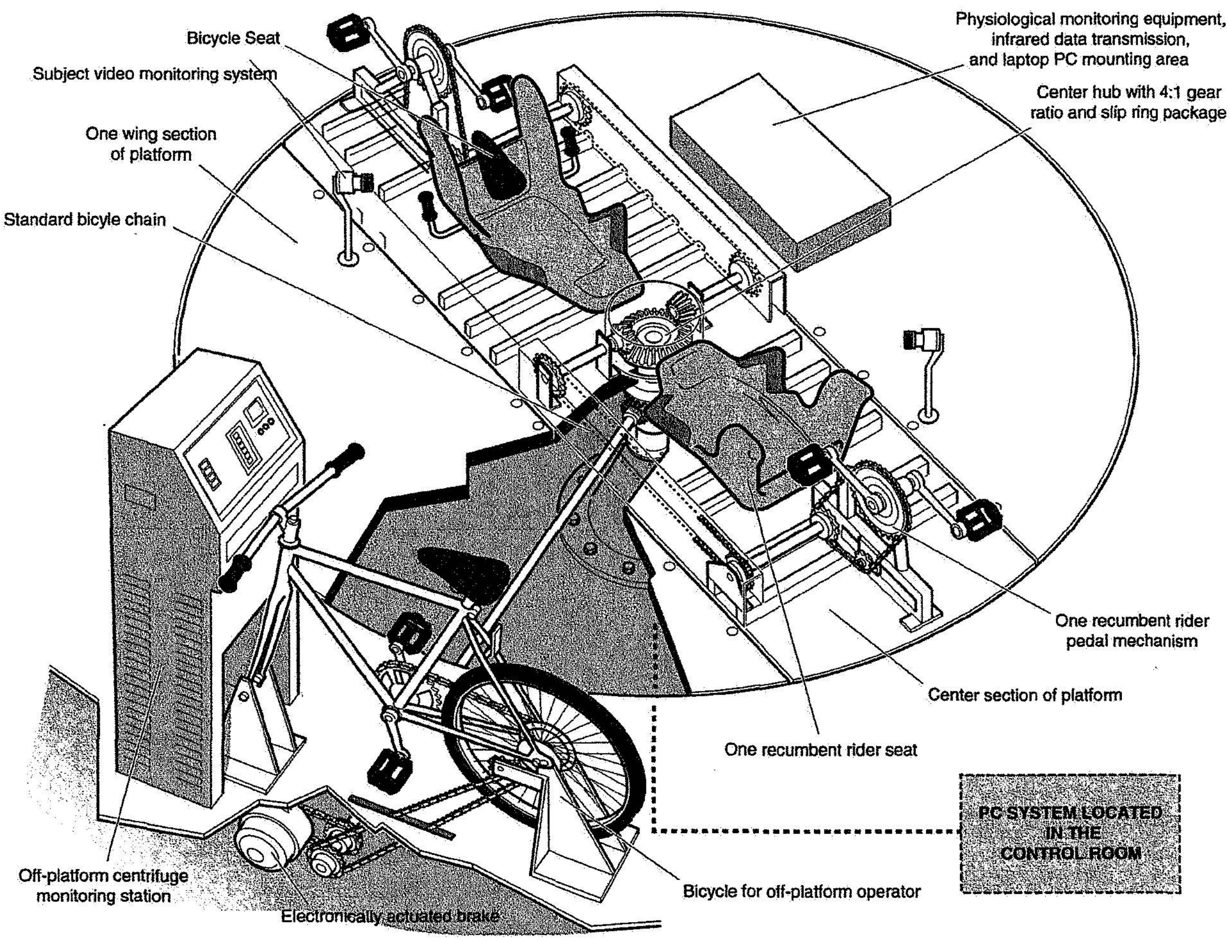
NASA/TM–2001-210926

Effect of Exercise Training and +Gz Acceleration Training on Men

John E. Greenleaf, Shawn R. Simonson, Jodie M. Stocks, Joyce Evans, Charles F. Knapp, Stephenie A. Cowell, Kendra N. Pemberton, Heather W. Wilson, Jamie M. Vener, Simon N. Evetts, Peter A. Hardy, Richard E. Grindeland, Helmut Hinghofer-Szalkay, Scott M. Smith, Michael G. Ziegler, David R. Brown, David G. Evans, Fritz B. Moore, and David T. Quach



September 2001

The NASA STI Program Office . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the Lead Center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.

- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.

- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.

- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.

- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.

- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at *http://www.sti.nasa.gov*

- E-mail your question via the Internet to help@sti.nasa.gov

- Fax your question to the NASA Access Help Desk at (301) 621-0134

- Telephone the NASA Access Help Desk at (301) 621-0390

- Write to:
  NASA Access Help Desk
  NASA Center for AeroSpace Information
  7121 Standard Drive
  Hanover, MD 21076-1320

NASA/TM–2001-210926

Effect of Exercise Training and +Gz Acceleration Training on Men

John E. Greenleaf[1], Shawn R. Simonson[2], Jodie M. Stocks[1], Joyce M. Evans[3], Charles F. Knapp[3], Stephenie A. Cowell[2], Kendra N. Pemberton[4], Heather W. Wilson[1], Jamie M. Vener[5], Simon N. Evetts[6], Peter A. Hardy[3], Richard E. Grindeland[1], Helmut Hinghofer-Szalkay[7], Scott M. Smith[8], Michael G. Ziegler[9], David R. Brown[3], David G. Evans[4], Fritz B. Moore[10], and David T. Quach[1]

[1]NASA Ames Research Center, Moffett Field, CA 94035-1000; [2]Lockheed Martin Space Operations Corporation, NASA Ames Research Center, Moffett Field, CA 94035-1000; [3]University of Kentucky, Lexington, KY 40506; [4]San Francisco State University, San Francisco, CA 94132; [5]California State University, Fresno, CA 93740-8018; [6]King's College London, London W8 7AH, England; [7]Institute for Adaptive and Spaceflight Physiology, A-8010 Graz, Austria; [8]NASA, Johnson Space Center, Houston, TX 77058-3696; [9]University of California, San Diego, CA 92103-8341; [10]University of California, Davis, CA 95616-8741

National Aeronautics and
Space Administration

Ames Research Center
Moffett Field, California 94035-1000

September 2001

Acknowledgments

The authors thank: for management and technical assistance – B.M. Asagi, P.R. Barnes, A. Bognar, T. Burchell, M. Crellin, J.B. Griffith, D.P. Gundo, J.F. Kaumeyer, J.A. Klem, M. Ludgate, S.G. Lumidao, C.M. McIntosh, R.T. Merlo, A.R. Patwardhan, T. Purcell, M.D. Smith, M. Stenger, and R.O. Talavera; for blood drawing – K. Campbell, J.D. Pavloff, and G. Shinn; for medical monitoring – B. Kharrazi, R. Pelligra, and S. Sastry; for manuscript preparation and editing – C.A. Barton, J.M. Donald, and L.N. Popish; and the test subjects for their splendid cooperation.

Extant Presentations and Publications

Evans, J.M., S.R. Simonson, C.K. Knapp, J.M. Stocks, H.W. Biagini, S.A. Cowell, K.N. Bailey, J.M. Vener, S.N. Evetts, F.B. Moore, M.B. Stenger, C.M. McIntosh, and J.E. Greenleaf. Differences in acceleration training and exercise training on resting cardiovascular variables. FASEB J. 14: A616, 2000. Abstract.

Evans, J.M., M.B. Stenger, E. Kwong, C.M. McIntosh, D.R. Brown, A.R. Patwardhan, C.F. Knapp, SR Simonson, JM Stocks, SA Cowell, KN Bailey, JM Vener, SN Evetts, FB Moore, and MG Ziegler.. Human powered centrifuge training on cardiovascular responses to head up tilt. FASEB J. 15: A795, 2001. Abstract.

Knapp, C.F., M.B. Stenger, E. Kwong, C.M. McIntosh, D.R. Brown, A.R. Patwardhan, J.M. Evans, S.R. Simonson, J.M. Stocks, H.W. Biagini, S.A. Cowell, K.N. Bailey, J.M. Vener, S.N. Evetts, F.B. Moore, and M.G. Ziegler. Passive acceleration training and cardiovascular responses to head up tilt. FASEB J. 15: A795, 2001. Abstract.

Pemberton, K.N.B. The Effects of Passive +Gz and Exercise Plus +Gz Training on Orthostatic Tolerance. M.A. Thesis; Department of Biology: Physiology and Behavioral Biology, San Francisco State University, September 2000. 84p.

Simonson, S.R., S.A. Cowell, J.M. Stocks, H.W. Biagini, J.M. Vener, S.N. Evetts, K.N. Bailey, J.M. Evans, C.F. Knapp, and J.E. Greenleaf. The impact of passive acceleration and exercise plus acceleration on work capacity and orthostasis. 13th I.A.A. Humans in Space Symposium: Exploring Space. Santorini, Greece, May 20-26, 2000.

Vener, J.M. Cardiopulmonary Responses to Incremental Supine Cycle Ergometry with Concomitant +Gz Acceleration. M.A. Thesis; Department of Kinesiology, California State University, Fresno, May 2000. 92p.

Available from:

NASA Center for AeroSpace Information
7121 Standard Drive
Hanover, MD 21076-1320
(301) 621-0390

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

CONTENTS

EFFECT OF EXERCISE TRAINING AND +Gz ACCELERATION TRAINING ON MEN

John E. Greenleaf[1], Shawn R. Simonson[2], Jodie M. Stocks[1], Joyce M. Evans[3], Charles F. Knapp[3], Stephenie A. Cowell[2], Kendra N. Pemberton[4], Heather W. Wilson[1], Jamie M. Vener[5], Simon N. Evetts[6], Peter A. Hardy[3], Richard E. Grindeland[1], Helmut Hinghofer-Szalkay[7], Scott M. Smith[8], Michael G. Ziegler[9], David R. Brown[3], David G. Evans[4], Fritz B. Moore[10], and David T. Quach[1]

SUMMARY

Reduction in work capacity (maximal oxygen uptake) during flight and enhanced orthostatic intolerance during reentry, landing, and egress from the return vehicle are continuing problems that have not been solved. Intermittent, high-intensity, short-duration isotonic cycle ergometer exercise training can maintain work capacity at ambulatory control levels over 1 month of bed-rest (BR)-deconditioning, and short-arm (< 2-meter radius) +Gz (head-to-foot) acceleration training without and with concomitant exercise can attenuate the usual orthostatic intolerance resulting from water-immersion or bed-rest deconditioning. Thus, the purpose for this study was to test the hypothesis that (1) passive-acceleration training; supine-interval-exercise plus acceleration training; and exercise combined with acceleration training would improve orthostatic tolerance in ambulatory men; and that (2) addition of the aerobic exercise conditioning would not alter this improved tolerance from that of passive-acceleration training.

Seven men (24–38 years) were test subjects. Three men underwent "Passive" training on the Ames human-powered centrifuge (HPC) for 30 min (warm-up, then 24 min of 2-min acceleration intervals (+1.0 Gz to 50% Gz_{max} at +2.4 ± 0.1 Gz), and cool-down) for 5 days/week for 3 weeks. Three other subjects underwent constant +Gz acceleration (50% of HPC maximal acceleration at +2.3 ± 0.2 Gz) while performing "Exercise" training on the cycle ergometer at 40% of maximal oxygen

---

[1]Laboratory for Human Environmental Physiology, NASA, Ames Research Center, Moffett Field, Calif. 94035-1000; [2]Lockheed Martin Space Operations Corporation, NASA, Ames Research Center, Moffett Field, Calif. 94035-1000; [3]Center for Biomedical Engineering, University of Kentucky, Lexington, Ky. 40506; [4]Department of Biology: Physiology and Behavioral Biology, San Francisco State University, San Francisco, Calif. 94132; [5]Department of Kinesiology, California State University, Fresno, Calif. 93740-8018; [6]Biomedical Sciences Division, King's College London, London W8 7AH, England; [7]Institute for Adaptive and Spaceflight Physiology, A-8010 Graz, Austria; [8]Life Sciences Research Laboratories, NASA, Johnson Space Center, Houston, Tex. 77058-3696; [9]GCRC, UCSD Medical Center, University of California, San Diego, Calif. 92103-8341; [10]Department of Neurology, Physiology, and Behavior, University of California, Davis, Calif. 95616-8741.

uptake ($\dot{V}O_2$max), then 24 min of 2-min intervals (40% - 90% $\dot{V}O_2$max) for 5 days/week for 3 weeks. A crossover design utilized 4 weeks of ambulatory deconditioning between sessions. Six subjects also underwent similar "Combined" exercise training at 40% to 90% of the HPC $+Gz_{max}$ exercise level. Before and after each training session the maximal $\dot{V}O_2$, workload, and heart rate (HR) were determined supine using a ramped cycle ergometer protocol. Resting HR and blood pressures (systolic, diastolic, and mean arterial) were measured, pre- and post-training, after 40 min of supine rest and for 1 min before determination of orthostatic tolerance to 70° head-up tilt.

Maximal human-powered (Passive, Exercise, Combined) data. Maximal supine exercise loads increased significantly ($P < 0.05$) by 8.3% (Passive Phase), 12.6% (Exercise Phase), and 15.4% (Combined Phase) after training, but the subjects' post-training maximal oxygen uptakes and maximal heart rates were unchanged from their respective pre-training levels. Maximal time to fatigue (endurance) was unchanged with Passive, but was also increased ($P < 0.05$) with Exercise and Combined training. Thus, the exercise in the Exercise and Combined training Phases resulted in greater maximal loads and endurance without effect on maximal oxygen uptake or heart rate.

Orthostatic (tilt-table) cardiovascular data. Resting pre-tilt heart rate was elevated by 12.9% ($P < 0.05$) only after Passive training, suggesting that the exercise training attenuated the HR response. Resting pre-tilt blood pressures (SBR, DBP, MAP) were not different pre- or post-training in any Phase. Post-training tilt-tolerance time and heart rate were increased ($P < 0.05$) only with Passive training, by 37.8% and by 29.1%, respectively. Thus, addition of exercise training appeared to attenuate the increased Passive tolerance. Resting (pre-tilt) and post-tilt cardiac R-R interval, stroke volume, end-diastolic volume, and cardiac output were all uniformly reduced ($P < 0.05$), and peripheral resistance was uniformly increased ($P < 0.05$) pre- and post-training for the three Phases, indicating no effect of the exercise training on these cardiovascular variables.

Orthostatic (tilt-table) biochemical data. Plasma volume (percent change) was uniformly decreased by 8% to 14% ($P < 0.05$) at tilt-tolerance pre-training versus post-training, indicating essentially no effect of training on the level of hypovolemia. The latter was reflected in the 6% to 12% ($P < 0.05$) increase in plasma aldosterone [PA] and plasma total protein [PTP] concentrations. Percent changes in plasma sodium concentration [PNa] pre-training versus post-training were minimal (less than -0.8%) as was plasma osmolality [POsm] (less than -0.4%) indicating essentially isotonic plasma shifts during tilting. Pre- and post-training percent changes in plasma renin activity (PRA), plasma aldosterone concentration [PA], plasma epinephrine concentration [PE], and [PNa] exhibited similar characteristic increases at tolerance; the usual increase in plasma vasopressin concentration [PVP] was greatly attenuated post-training with Exercise and also pre- and post-training with Combined. The explanation for the latter is not obvious but is unlikely a result of technical errors.

Urine data (24-hr). Urinary volumes were within normal limits (1.2 to 1.5 $ml \bullet min^{-1}$) between and among pre- and post-training samples for the three Phases. There were no significant differences between or among the 10 urinary variables pre-training and post-training for the three Phases.

INTRODUCTION

Long-duration (> 1-yr) human spaceflight will require refinement of current physiological countermeasures, as well as implementation of others to allay deconditioning of crew members – defined as attenuation of their physical fitness. Crew exposure to weightlessness in the spaceflight environment of moderate confinement, restricted mobility, and enhanced ionizing radiation affects every organ system in the body that contributes to deconditioning (Convertino, 1990; Nicogossian, 1994; Sonnenfeld, 1998; Zerath, 1998). Effects of deconditioning such as reduction of maximal work capacity (Greenleaf et al., 1989), bone density and strength (LeBlanc et al., 1990, 1996), muscle mass and strength (Ellis et al., 1993; Greenleaf et al., 1994), orthostatic tolerance (Buckey et al., 1996), and neurovestibular sensitivity (Collins et al., 1995; Paloski et al., 1992) can lead to decreased crew health, safety, and productivity during flight, especially during and immediately after landing on a planet with a physiologically significant gravitational force (Buckey et al., 1996; Burton, 1988; Kotovskaya et al., 1977; Nicogossian, 1994).

Short arm (< 2-m radius) +Gz (head-to-foot) acceleration training without (Shulzhenko et al., 1976, 1979; Vil-Viliams, 1994) and with (Vil-Vilyams and Shulzhenko, 1980) concomitant exercise training has been reported to significantly attenuate the usual orthostatic intolerance resulting from water-immersion deconditioning. In addition, the data of White et al. (1966) indicated that the consistent intolerance to 20 min of 70° head-up tilt after prolonged BR-deconditioning was reduced or alleviated by daily intermittent +1.75 Gz (4.7 G-hr) training periods without exercise during 10 days of horizontal BR as reviewed by Stone et al. (1966). Also, intensive, intermittent cycle ergometer exercise training can maintain aerobic exercise capacity (maximal oxygen uptake) at ambulatory control levels during 30 days of 6° head-down BR (Greenleaf et al., 1989; Kakurin et al., 1978). Performing exercise with acceleration has been proposed as a time-efficient countermeasure to attenuate the reduction in both exercise capacity and orthostatic tolerance simultaneously during deconditioning (Burton, 1988; Greenleaf et al., 1999; Shulzhenko et al., 1976; Vernikos, 1997; Vil-Vilyams and Shulzhenko, 1980).

The efficacy of these two countermeasures, singly or in combination, has not been confirmed on most physiological systems after prolonged BR-deconditioning. As a result, there are many questions to be addressed. For example: What is the most effective duration and intensity of exercise and acceleration? When performed simultaneously, do these two treatments interfere with each other? Will the muscle pumping action of exercising legs interfere with acceleration-induced caudal fluid shifts? Does daily exercise-acceleration training have salutary or adverse effects on the muscular, neurovestibular, or skeletal systems?

The first studies utilizing the human-powered centrifuge (HPC) (Mulenburg and Vernikos, 1997) at Ames Research Center (ARC) began in 1995 (Chou, 1997; Chou et al., 1998; Greenleaf et al., 1997, 1999; Stad, 1998; Vener, 2000) and were designed to familiarize the investigators with its operating characteristics, procedures, and linearity of its loads as an exercise ergometer. Chou et al. (1997) have annotated most of the literature concerning the effects of exercise and acceleration training on deconditioning through 1996.

The purpose of this study was to investigate exercise and acceleration training (singly and in combination) on metabolic, orthostatic, and blood and urine factors to provide background data in

preparation for a more extensive BR-deconditioning-training study. It was hypothesized that the three training protocols (Passive, Exercise, and Combined, all utilizing head-to-foot acceleration) would preserve normal orthostatic responses during tilt, and that the aerobic exercise conditioning stimuli would not alter those +Gz training responses.

METHODS

Approval

This experimental protocol entitled "Exercise Training on the Short-Arm Centrifuge" was approved by the San Francisco State University Committee for the Protection of Human Subjects on 8 May 1998, and by the ARC Human Research Institutional Review Board on 4 January 1999 (H.R. No. 158 was replaced by No. 191). Approval of Dr. R. E. Grindeland's addendum was granted on 16 February 1999, and for a 1-month extension of H.R. No. 191 on 8 November 1999 (appendixes A1 – A4). Study data were collected from 14 June through 19 December 1999.

Subjects

The male test subjects were recruited from San Jose State University students and ARC employees and contractors. Seven men (table 1) were selected who were not currently involved in a regular physical training program, and who had no tobacco or nonprescriptive drug use. After extensive presentations of the experimental requirements and potential hazards by the investigators and medical monitor, the subjects signed informed consent forms and passed a comprehensive medical examination including history, electrocardiogram, blood and urine chemistry panels, and an exercise stress test prior to data collection.

Human-Powered Centrifuge

Design, construction, operation, and instrumentation. The HPC, designed and constructed at Ames Research Center, is a short-arm (1.9 m) dual-couch machine powered by a chain-linked cycle driven by the subject's legs (fig. 1)*. The revolving circular platform assembly consists of three lightweight aluminum honeycomb and bonded aluminum sections – a center section and two wings weighing a total of 295 kg. The center section, which rides on tapered roller bearings (Timken), supports the two couches and the chain-drive pedal mechanism. Bevel gears (Boston, 4:1 gear ratio) transform pedaling power to platform rotation. The two wings, bolted to the center section, provide areas for walking and

---

* Figures 1–11 are in the main text at the point of citation; figures 12-57 appear at the end of the report. In text, bracketed abbreviations designate concentrations; for example, plasma total protein [PTP]. Simple initials are enclosed in the conventional parentheses following their definitions; for example, plasma renin activity (PRA).

Table 1. Test subject characteristics.

Subject	Phase	Age, yr	Ht, cm	Wt, kg	S.A., m^2	PV, ml	TBV, ml	$\dot{V}O$ max, $L \cdot min^{-1}$	$\dot{V}O$ max, $ml \cdot min^{-1} \cdot kg^{-1}$	HR_{max}, $b \cdot min^{-1}$	$+Gz_{max}$, G	RH_{max}, $b \cdot min^{-1}$
FLE	III	32	172.0	71.7	1.82	3300	5172	2.62	37	166	4.40	174
FRE	I II III	38	176.0	89.8	2.10	3781	5609	3.44	38	170	4.51	180
HUN	I II III	38	186.0	96.8	2.14	3616	6092	2.69	28	174	4.50	186
JAG	I II III	24	180.5	85.6	2.07	3493	5829	3.18	38	186	4.94	192
RAY	I II III	27	178.0	83.0	2.01	3457	5510	3.31	40	188	5.47	179
RUI	I II III	38	177.0	86.0	2.03	4486	7437	3.16	37	159	4.90	161
SCH	I II	30	172.5	76.5	1.88	2864	4535	2.86	37	188	5.03	186
$\overline{X}$		32	177.4	84.2	2.01	3571	5741	3.04	36	176	4.82	180
SD		6	4.8	8.3	0.12	496	900	0.32	4	12	0.38	10

Phase I – Passive acceleration; Phase II – Exercise acceleration; Phase III – Combined acceleration.
PV = plasma volume; TBV = total blood volume.

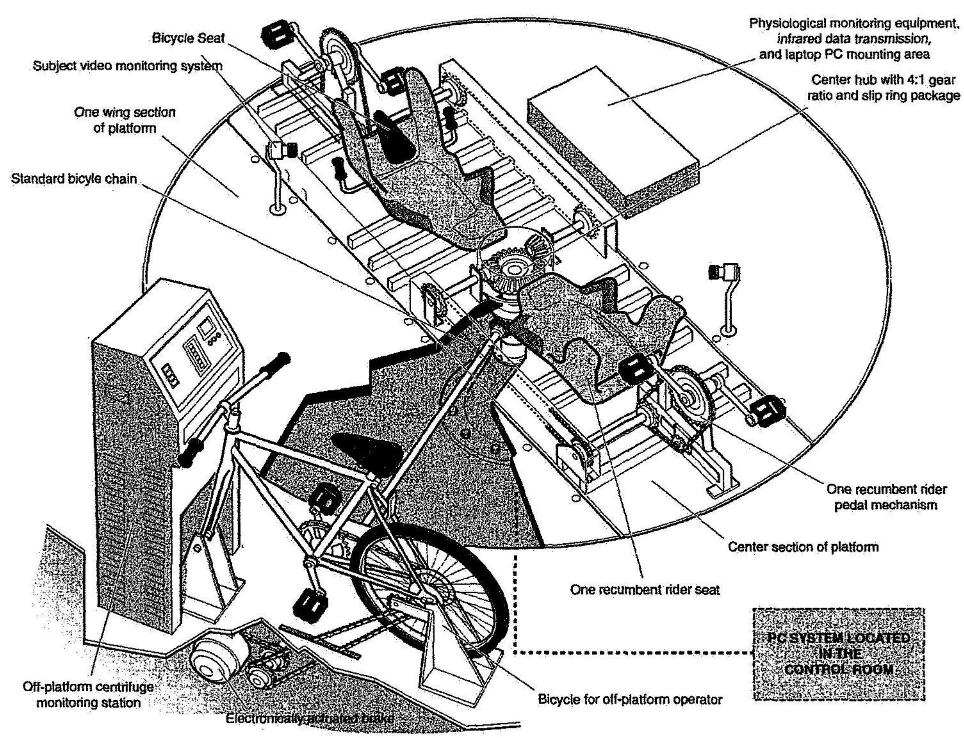


Figure 1. The Human Powered Centrifuge

for mounting instrumentation. The three pedaling stations, two on-board at the end of the couches and the third located on the off-board operator's stationary cycle, are linked by standard bicycle chains and sprockets to the center hub. The top of the subject's head is located about 26 cm from the center of rotation, and the level of acceleration is calculated 1.9 m (6 ft) from the center of rotation. One 360° rotation of the platform requires 1.6 pedal sprocket rotations. Tables of acceleration as a function of angular velocity are given in appendixes B1 and B2.

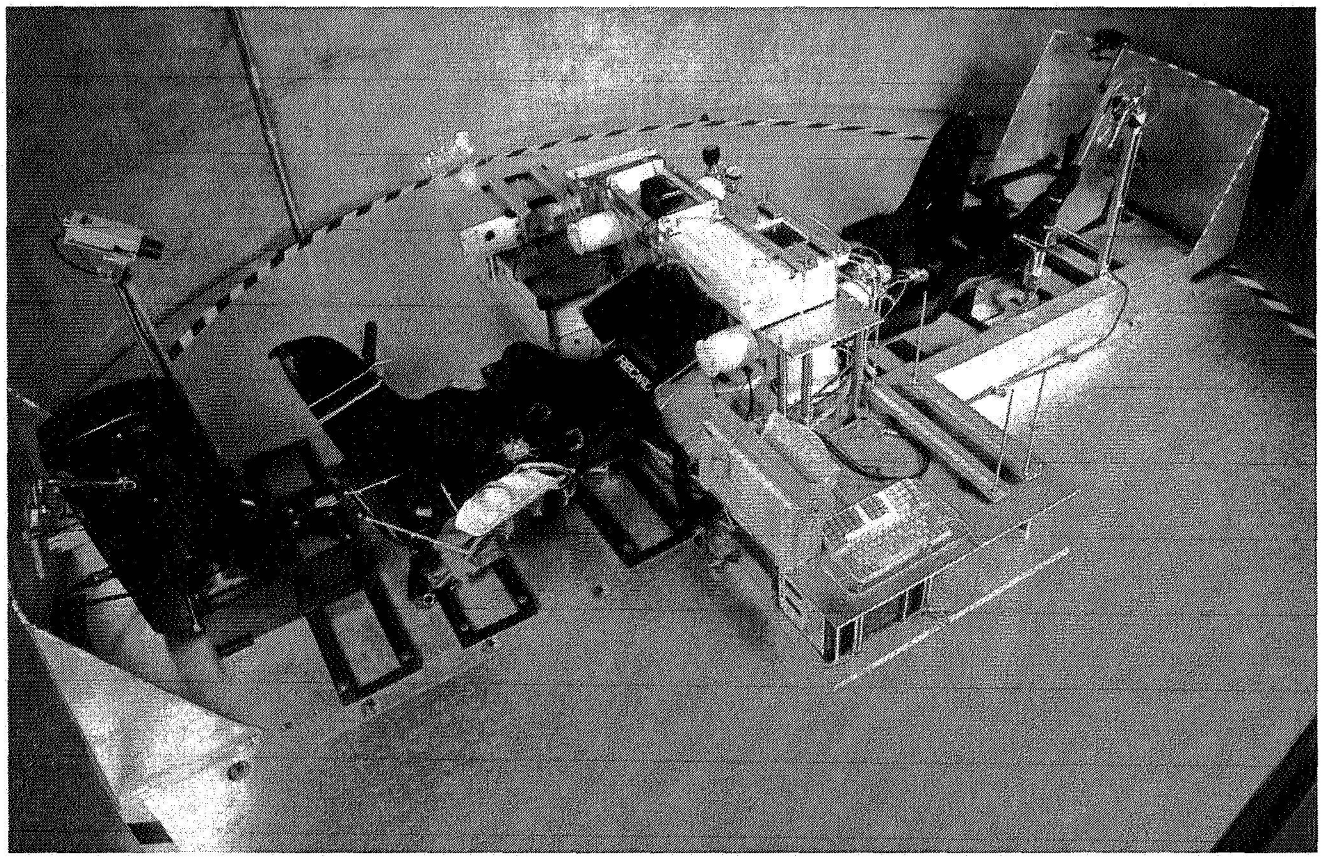
The on-board subject and the off-board operator can actuate and control platform angular velocity (revolutions/min, rpm), but only the operator can stop the platform with a spring-set disc brake (Stearns series 87,300, model 1-087-352-00, Rexnord Corp., Milwaukee, Wis.) activated electronically by the operator or test subject. Centrifuge parameters, such as rpm (model H25D-SB encoder, BEI Motions Systems, Co., Goleta, Calif., and model P6020 tachometer, Newport Electronics, Inc., Santa Ana, Calif.; total accuracy of 0.0002%) and G-level, are displayed on the control panel of the monitoring station. The center hub-drive differential has a slip-ring assembly (model 1067, Fabricast, South El Monte, Calif.) that transmits physiological data electrically from the on-board test subjects to instruments in the adjoining control room (fig. 1).

In the current configuration, the second on-platform pedaling station is a standard independent cycle ergometer (model 845, Quinton Ergometer, Seattle, Wash.) that is not connected for platform rotation (fig. 2). For rotation while pedaling this ergometer, one of the other two pedaling stations must be engaged. There are three video cameras: one by each couch aimed at the subject's head, and the third covering the entire centrifuge. Subject energy output was measured with a metabolic (oxygen) analyzer (CPX Express, MedGraphics Corp., St. Paul, Minn.) with data downloaded and stored at the end of each run with a model H-1330 (Quantax Microsystems Corp., Somerset, N.J.) laptop computer, and then printed on the MedGraphics printer (model BJC, Canon Hi-Tech, Thailand). Heart-rate data were taken from the electrocardiogram (model 78202, Hewlett-Packard, Palo Alto, Calif.) and displayed in the control room. Information about all instruments and equipment is presented in appendix C.

Protocol

This study consisted of a 2-week pre-training period, three 3-week centrifuge training periods separated by two 4-week ambulatory recovery (deconditioning) periods, and a 4-week post-training ambulatory recovery (deconditioning) period (fig. 3). Daily protocols are presented in appendix D. The exercise and acceleration training regimens were conducted in three Phases:

Phase I (Passive acceleration) required the supine, resting subjects (no exercise) to ride the centrifuge at relative, intermittent loads that stepped between 25% and 50% of their maximal +Gz acceleration ($+Gz_{max}$), provided by the off-platform cycle operator. Each subject underwent a 6-min warm-up at 25% followed by alternating 25% and 50% loads at 2-min intervals (0.008 Hz) for 30 min (fig. 4). The range of 50% $+Gz_{max}$ levels was 2.2 G to 2.5 G at the foot (table 2).



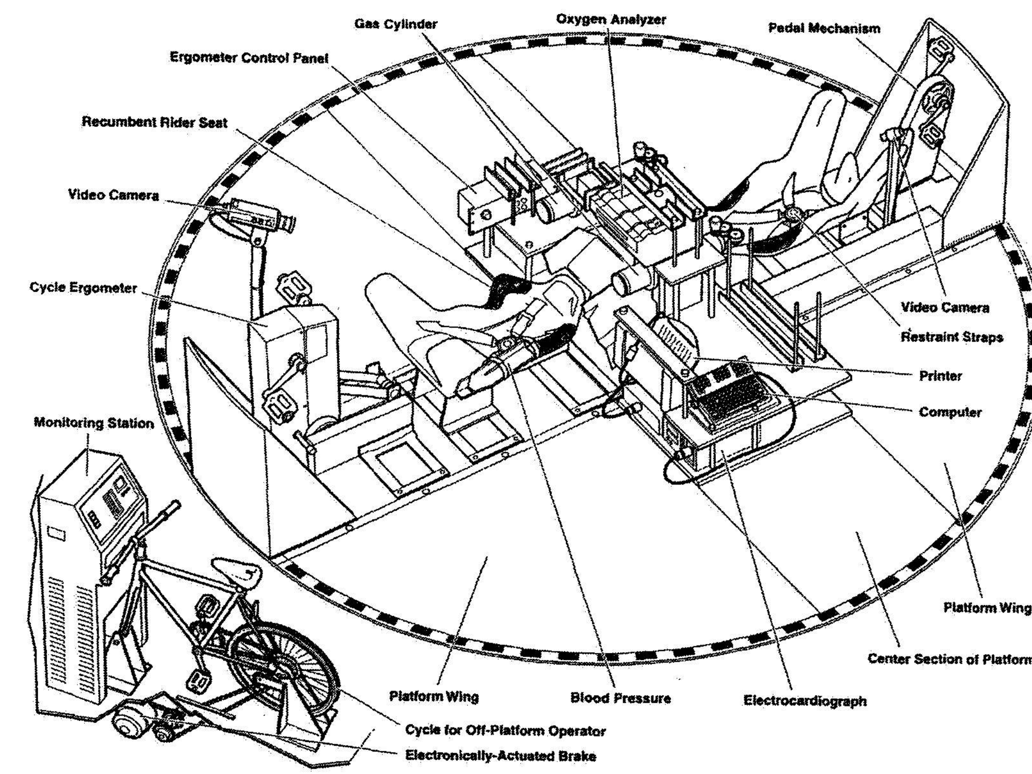


Figure 2. The Human Powered Centrifuge, top, bottom.

Figure 3(a). Experimental Protocol (Overview).

Baseline July 12 2 weeks July 23	I: Centrifuge Training Passive + Exercise July 26 3 weeks Aug 13	Recovery (deconditioning) Aug 16 4 weeks Sept 10	II: Centrifuge Training Exercise + Passive Sept 13 3 weeks Oct 1
↑ (BS) Tilt ↑ (BS) TILT (BS) ↑ MRI ↑ UA ↑ UA ↑ maxVO$_2$ ↑ +GzVO$_2$	(14 training sessions) (1 tilt test on day 15) ↑ (BS) TILT (BS) ↑ UA	↑ maxVO$_2$ ↑ (BS) TILT (BS) ↑ MRI ↑ MRI ↑ UA ↑ maxVO$_2$ ↑ +GzVO$_2$	(14 training sessions) (1 tilt test on day 15) ↑ (BS) TILT (BS) ↑ UA
	Group A; N=3 (exercise acceleration)* Group B; N=3 (passive acceleration)**		Group A; N=3 (passive acceleration)** Group B; N=3 (exercise + acceleration)*

Recovery (deconditioning) Oct 4 4 weeks Oct 29	III: Centrifuge Training Combined (HPC) Nov 1 3 weeks Nov 19	Recovery (deconditioning) Nov 22 4 weeks Dec 17
↑ maxVO$_2$ ↑ (BS) TILT (BS) ↑ MRI ↑ MRI ↑ UA ↑ maxVO$_2$ ↑ +GzVO$_2$	(14 training sessions) (1 tilt test on day 15) ↑ (BS) TILT (BS) ↑ UA	↑ maxVO$_2$ ↑ (BS) TILT (BS) ↑ MRI ↑ MRI ↑ UA ↑ maxVO$_2$ ↑ +GzVO$_2$
	Groups A + B, N=6 (combined acceleration)***	

Tilt tests will be performed 1–2 days before pre-training and on the last day of the centrifuge training periods.
MRI tests will be performed 2–3 days before pre-training and 1 day after the centrifuge training periods.
Max VO$_2$ will be measured within a week before and 2 days after the centrifuge training periods.
Max +Gz VO$_2$ will be measured within a week before the centrifuge training periods.
UA: Urine analysis for markers of bone remodeling will be made from a 24-hr collection prior to tilt.
BS: Blood samples will be drawn before and after each tilt test.

* Exercise + acceleration = alternating ergometer exercise + constant off-platform acceleration.
** Passive acceleration = alternating off-platform acceleration.
*** Combined acceleration = human-powered centrifuge acceleration alternating exercise and accompanying acceleration.

Buildup and Phase 1: Passive (P) and Exercise (E) Acceleration Training Schedule.

	Wk	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Build Up	June 14 - 20		Supine **Practice** Part 1		Supine **Practice** Part 2	Supine **Practice** Part 2		
	June 21 - 27	9am Pract **$\dot{V}O_2$max** Part 2		9am Pract **HPCmax** Part 1		9am Pract **HPCmax** Part 2		
	JunJul 28 - 4							
	July 5 – 11	Lab Closed		Subject Orientation Day *	Upright $\dot{V}O_2$max Part 2	Practice **Tilt[B]** ↔ Urine Coll		
I	July 12 – 18	Supine $\dot{V}O_2$max Part 1	Supine $\dot{V}O_2$max Part 2 Trial	Prelim HPCmax Part 1	Pract **Tilt**	Prelim Tilt[B]	MRI	
Pre-Train	July 19 – 25	Study $\dot{V}O_2$max Part 2	Practice HPC P & E	Study HPCmax Part 2		Study Tilt[B] ↔ *Urine Coll*		
Train	JulAug 26 -1	30min P E	30min P E	30min P E	30min P E	30min P E		
	Aug 2 - 8	30min P E	30min P E	30min P E	30min P E	30min P E		
	Aug 9 - 15	30min P E	30min P E	30min P E	30min P E	Study Tilt[B] ↔ *Urine Coll*	MRI	
Recov	Aug 16 – 22	Study $\dot{V}O_2$max Part 2						
	Aug 23 - 29							
	AugSep 30 - 5							
	Sep 6 - 12	Study $\dot{V}O_2$max Part 2		Study HPCmax Part 2		Study Tilt[B] ↔ *Urine Coll*	MRI	

Phase II: Exercise and Passive Acceleration Training Schedule.

	Wk	Mon	Tue	Wed	Thu	Fri	Sat	Sun
II	Sep 13 - 19	30min E P	30min E P	30min E P	30min E P	30min E P		
Train	Sep 20 - 26	30min E P	30min E P	30min E P	30min E P	30min E P		
	SepOct 27 – 3	30min E P	30min E P	30min E P	30min E P	Study Tilt[B] ↔ *Urine Coll*	MRI	
Recov	Oct 4 – 10	Study $\dot{V}O_2$max Part 2						
	Oct 11 – 17							
	Oct 18 - 24							
	Oct 25 – 31	Study $\dot{V}O_2$max Part 2		Study HPCmax Part 2		Study Tilt[B] ↔ *Urine Coll*	MRI	

Phase III: Combined (HPC) Acceleration Training Schedule.

	Wk	Mon	Tue	Wed	Thu	Fri	Sat	Sun
III	Nov 1 – 7	30min HPC	30min HPC	30min HPC	30min HPC	30min HPC		
Train	Nov 8 – 14	30min HPC	30min HPC	30min HPC	30min HPC	30min HPC		
	Nov 15 – 21	30min HPC	30min HPC	30min HPC	30min HPC	Study Tilt[B] ↔ *Urine Coll*	MRI	
Recov	Nov 22 – 28	Study $\dot{V}O_2$max Part 2						
	NovDec 29 – 5							
	Dec 6 – 12							
	Dec 13 - 19	Study $\dot{V}O_2$max Part 2		Study HPCmax Part 2		Study Tilt[B] ↔ *Urine Coll*	MRI	

LEGEND

(white box)	=	No test subjects involved.
(shaded box)	=	Test subjects involved.

* Orientation	=	Subject familiarization with HPC, tilt, supine ergometer and $\dot{V}O_2$max
Tilt[B]	=	Tilt to +70° from horizontal for approximately 1 hr + blood samples.
Study	=	Measures to be used for study analysis.
$\dot{V}O_2$ max Pt 1	=	Maximal oxygen uptake preliminary assessment.
$\dot{V}O_2$ max Pt 2	=	Maximal oxygen uptake main assessment.
MRI	=	Magnetic resonance imaging (noninvasive scan).
HPCmax Pt 1	=	Maximal oxygen uptake + centrifugation preliminary assessment .
HPCmax Pt 2	=	Maximal oxygen uptake + centrifugation main assessment.
P	=	Subjects undertake passive centrifugation.
E	=	Subjects undertake exercise during centrifugation.
↔ Urine Coll	=	24-hr urine collection.

Figure 3(b).

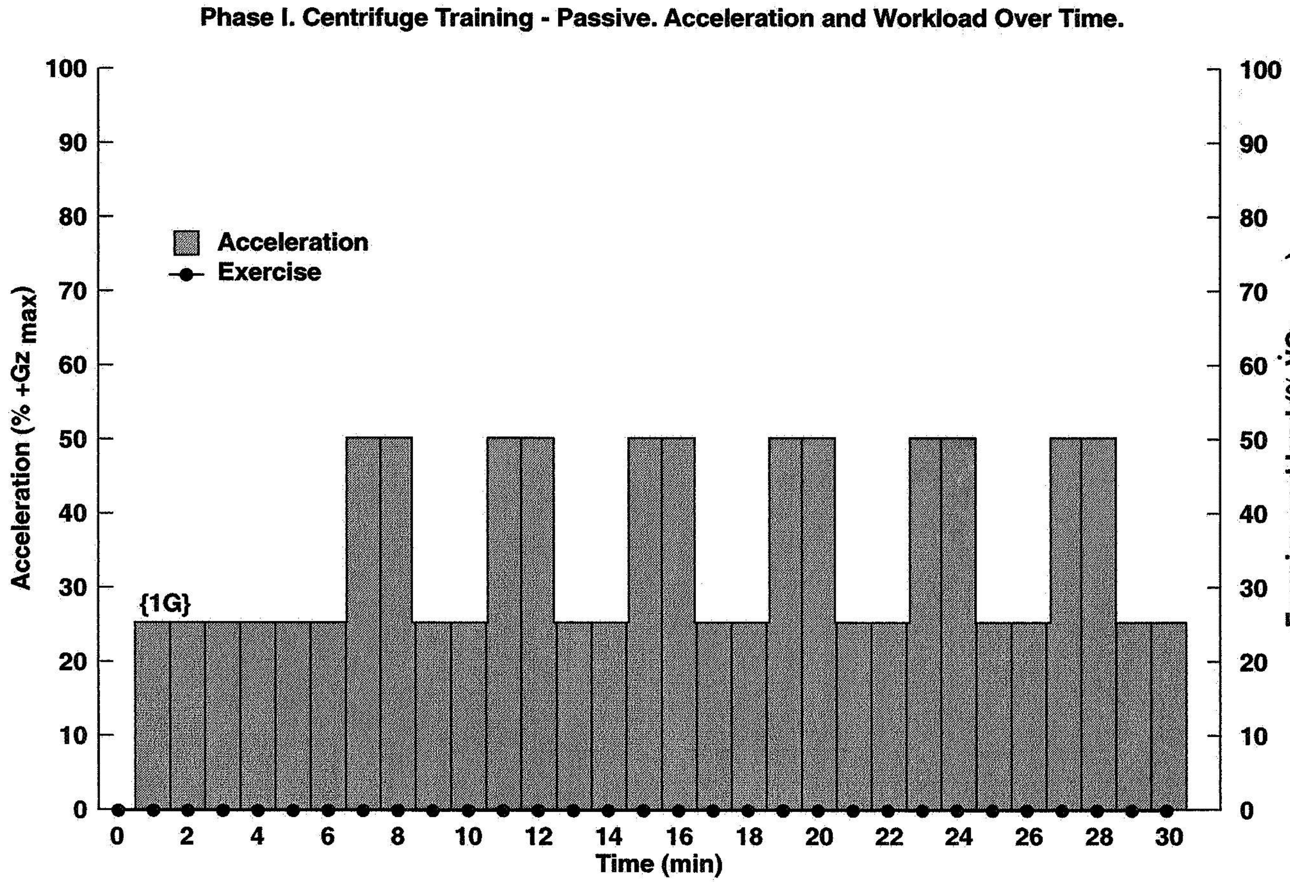


Figure 4,

The Phase II (Exercise acceleration) protocol consisted of supine, oscillatory leg ergometer exercise varying from 40% of maximal oxygen uptake ($\dot{V}O_2$max) to 90% $\dot{V}O_2$max in alternating 2-min intervals (fig. 5). The constant 50% $+Gz_{max}$ acceleration load was provided by the off-board operator.

Phases I and II were conducted using a cross-over design with three subjects (Group A) undergoing exercise acceleration and three subjects (Group B) undergoing passive acceleration first; followed by the reverse in Phase II (fig. 1). The ranges of exercise loads (kg-m•min^{-1}) in Phase II were: 40% (600-800), 50% (750-1,000), 60% (900-1,200), 70% (1,050-1,400), 80% (1,200-1,600), and 90% (1,350-1,800) (table 2).

Phase III (Combined acceleration) had the subjects exercising on the HPC arm of the centrifuge where their leg exercise drives the centrifuge; that is, the exercise and the acceleration were performed by the subjects. Here the 40% to 90% loads were determined previously from the $+Gz_{max}$ on the HPC arm expressed in revolutions per minute (fig. 6). The ranges of relative exercise acceleration (G-levels) were: 40% (1.8-2.2), 50 % (2.2-2.8), 60% (2.6-3.3), 70% (3.1-3.9), 80% (3.5-4.4), and 90% (4.0-5.0) (table 2 and appendix B).

Table 2. Individual +Gz $_{max}$ levels for the seven men during the three Phases.

		FLE	FRE	HUN	JAG	RAY	RUI	SCH	
I	100% +Gz max	4.40	4.51	4.50	4.94	5.47	4.90	5.03	G
	Passive	—	13 Sept	13 Sept	26 July	26 July	26 July	13 Sept	
	50% +Gz max	—	2.2	2.2	2.4	2.5	2.5	2.5	G
II	Exercise (ergometer)	—	26 July	26 July	13 Sept	13 Sept	13 Sept	26 July	
	50% +Gz max	—	2.4	1.8	2.5	2.8	2.4	2.2	G
	Load in kg-m • min^{-1}								
	40%	—	600	600	800	800	800	600	
	50%	—	800	750	1000	1000	1000	750	
	60%	—	1000	900	1200	1200	1100	900	
	70%	—	1100	1050	1400	1400	1300	1050	
	80%	—	1300	1200	1600	1600	1500	1200	
	90%	—	1400	1350	1800	1800	1700	1350	
III	Combined (HPC)	1 Nov	1 Nov	1 Nov	1 Nov	1 Nov	1 Nov		
	Load in +Gz units								
	40%	1.8	1.9	1.8	1.9	2.2	2.1	—	
	50%	2.2	2.4	2.2	2.4	2.8	2.6	—	
	60%	2.6	2.8	2.6	2.9	3.3	3.1	—	
	70%	3.1	3.3	3.1	3.4	3.9	3.6	—	
	80%	3.5	3.8	3.5	3.8	4.4	4.2	—	
	90%	4.0	4.3	4.0	4.3	5.0	4.7	—	

The subjective intensity of perceived stress during the training sessions was noted by the subjects on the Borg (1982) scale (appendix D).

Tests and Measurements

Maximal oxygen uptake ($\dot{V}O_2$max) protocol. Maximal working capacity was measured in the pre-training period with the subjects in the upright (sitting) and supine body positions (table 3) on calibrated electronically-braked ergometers (models 845 sitting and 846T supine, Quinton, Seattle, Wash.) where work output was independent of pedal rpm. Sitting and supine exercise were used prior to exercise-training data collection to familiarize the subjects with the protocol and to determine their maximal exertion data. The supine position was then used for all subsequent maximal exercise protocols at both positions on the centrifuge: the isolated Quinton (model 845) ergometer at one couch

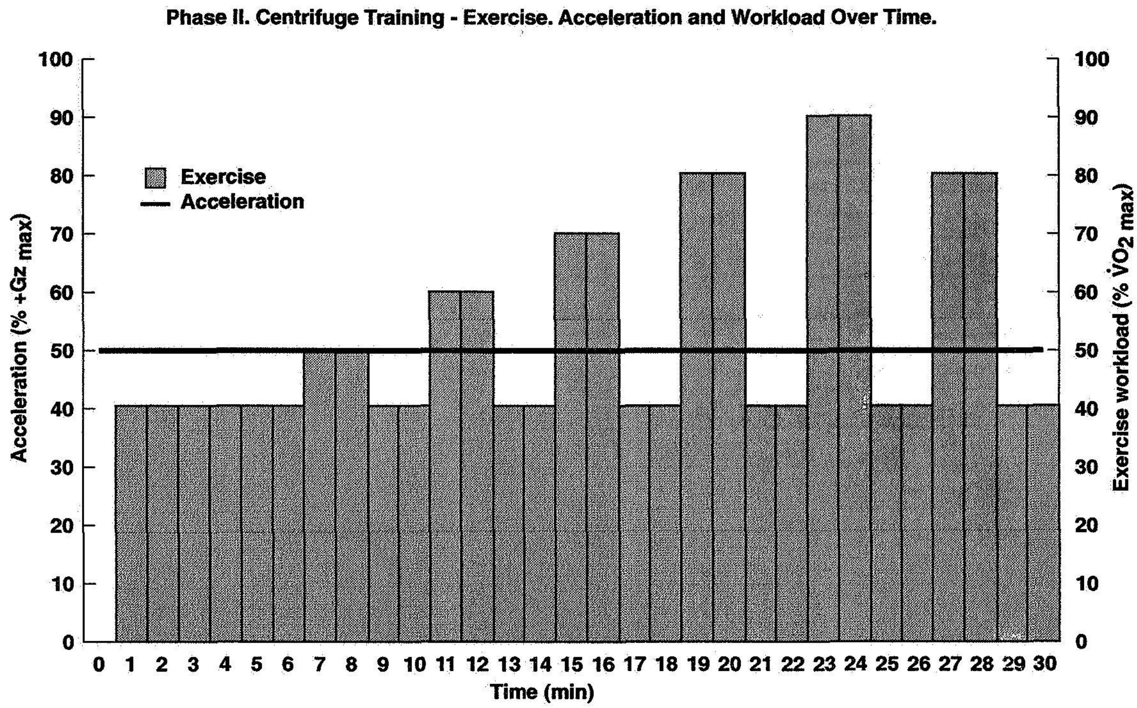


Figure 5.

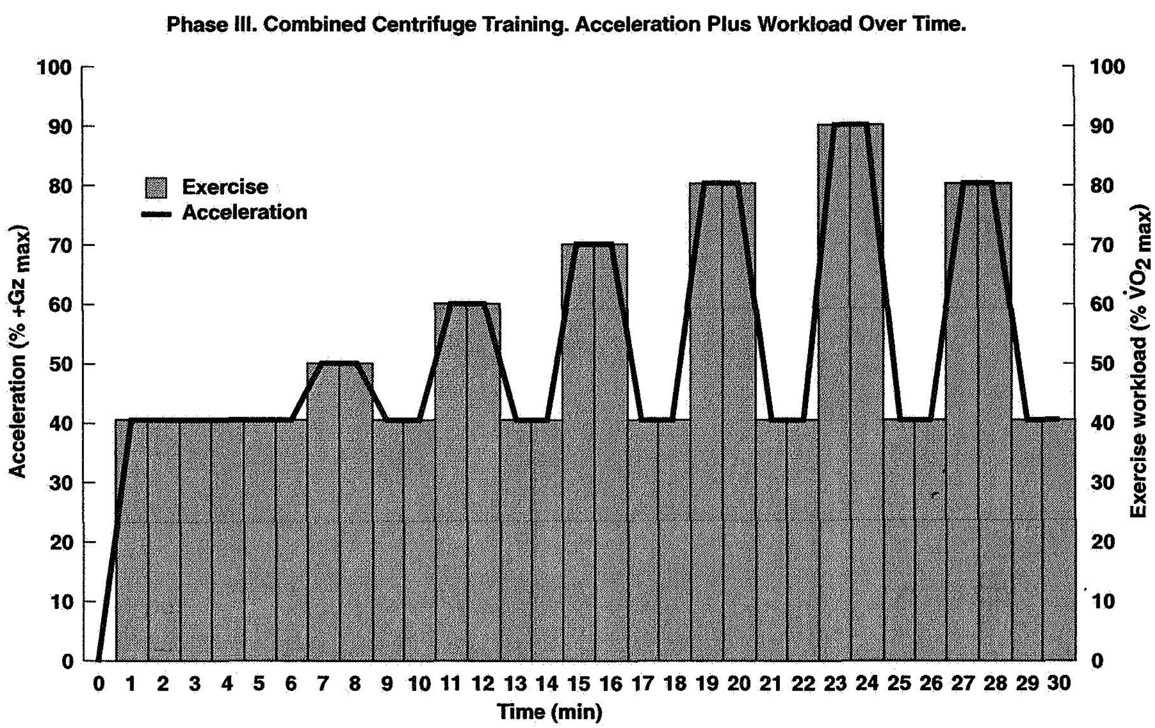


Figure 6.

Table 3. Individual pre-training supine maximal ergometer exercise data on the seven men.

		Oxygen uptake,		RER	Heart rate,	$\dot{V}_E$,	Exerc. load,	RPE
		$L \cdot min^{-1}$	$ml \cdot kg^{-1} \cdot min^{-1}$		$b \cdot min^{-1}$	$L \cdot min^{-1}$	$kg\text{-}m \cdot min^{-1}$	
FLE		2.62	37.0	1.36	166	104	1600	10
FRE		3.44	38.3	1.21	170	115	1800	10
HUN		2.69	27.9	1.21	174	102	1500	10
JAG		3.18	37.9	1.28	186	111	1800	10
RAY		3.31	39.6	1.28	188	138	1700	10
RUI		3.16	36.7	1.25	159	122	1900	9
SCH		2.86	37.2	1.26	188	99	1500	10
$\bar{X}$		3.04	36.4	1.26	176	113	1686	10
SD		0.32	3.9	0.05	12	14	157	0
SE		0.12	1.5	0.02	4	5	59	0

RER = respiratory exchange ratio; $\dot{V}_{E\ BTPS}$ = ventilation; RPE = rated perceived exertion.

and the combined HPC exercise + acceleration station at the other couch (fig. 7). The subjects were secured to the couches with shoulder braces and a four-point shoulder and lap harness; handgrips were used for body stabilization and leverage during the maximal tests. Thus arm, shoulder, and trunk muscular contractions were added to the lower leg exercise metabolism in determining $\dot{V}O_2$max. A preliminary continuous HPC $\dot{V}O_2$max test (Part 1) was performed 3 to 4 weeks before the main experiments in order to estimate the maximal workload (70 rpm with 300 kg-m•min^{-1} increments until heart rate reached 180 b•min^{-1} or volitional fatigue occurred); this was followed by a 5-min cooling-down period (fig. 8, left panel). After at least 3 days of recovery, the maximal exercise protocol (Part 2) was performed again (fig. 8, right panel) where the subjects warmed up at 70 rpm at about 40% of their maximal workload (O_2 uptake) determined in Part 1 above. They then exercised for 2-min intervals at progressively greater workloads starting at about 400 kg-m•min^{-1} below the Part 1 estimated maximal load and continuing to 200 kg-m•min^{-1} below maximal; then the maximal load was undertaken. If the subjects completed 2 min at this "maximal" load, it was increased by 200 kg m•min^{-1} each min until a heart rate of 180 b•min^{-1} or volitional fatigue occurred. A 5-min cooling-down period followed. This abbreviated maximal testing protocol was used to minimize training effects. Heart rate, integrated from the ECG, and ratings of perceived exertion (RPE) were recorded during all maximal tests.

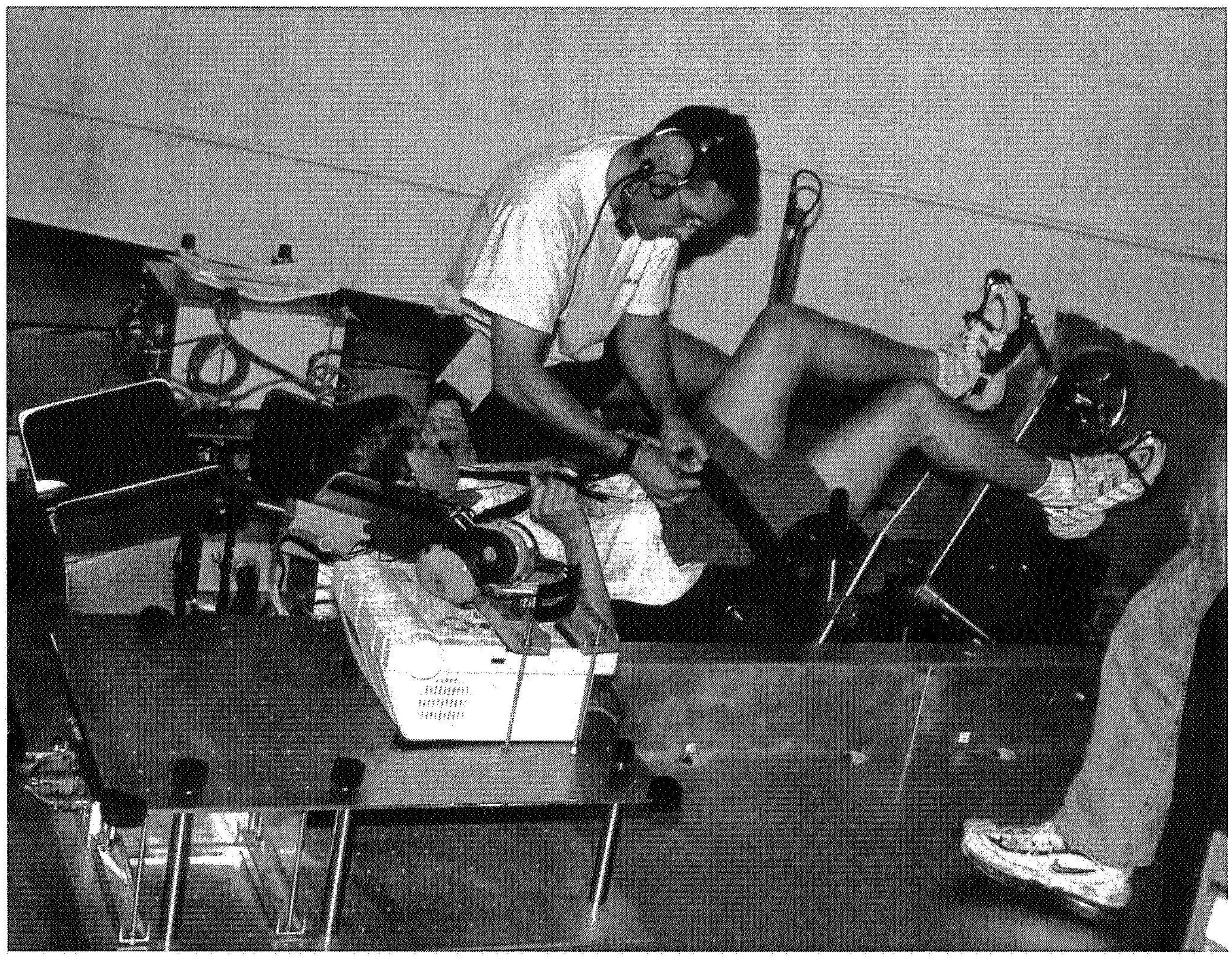


Figure 7.

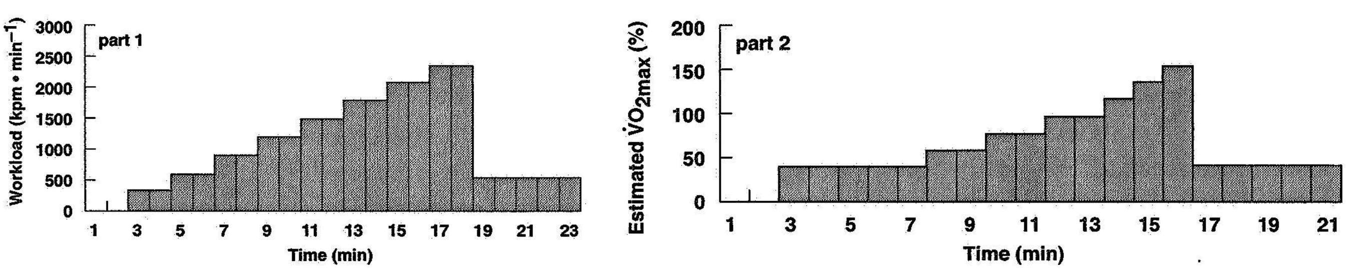


Figure 8

Maximal human-powered centrifuge protocol. Pre-training familiarization tests and tolerances were determined with the HPC (Greenleaf et al., 1999) 3 to 4 weeks before the experiments began (fig. 3). The subjects were secured in the couch with the 4-point restraint harness and to the pedals with toe-clips and Velcro® straps; a blindfold was worn for all acceleration runs and radio headsets (model H3391, David Clark Co., Inc., Worchester, Mass.) were used to maintain communications among the subject, research team, and medical monitor (fig. 9). The preliminary HPC test (Part 1) consisted of a 9-min warm-up period at +0.5 Gz followed by 4 min at +1.0 Gz, 2-min rest, 4 min at +2.0 Gz, 2-min

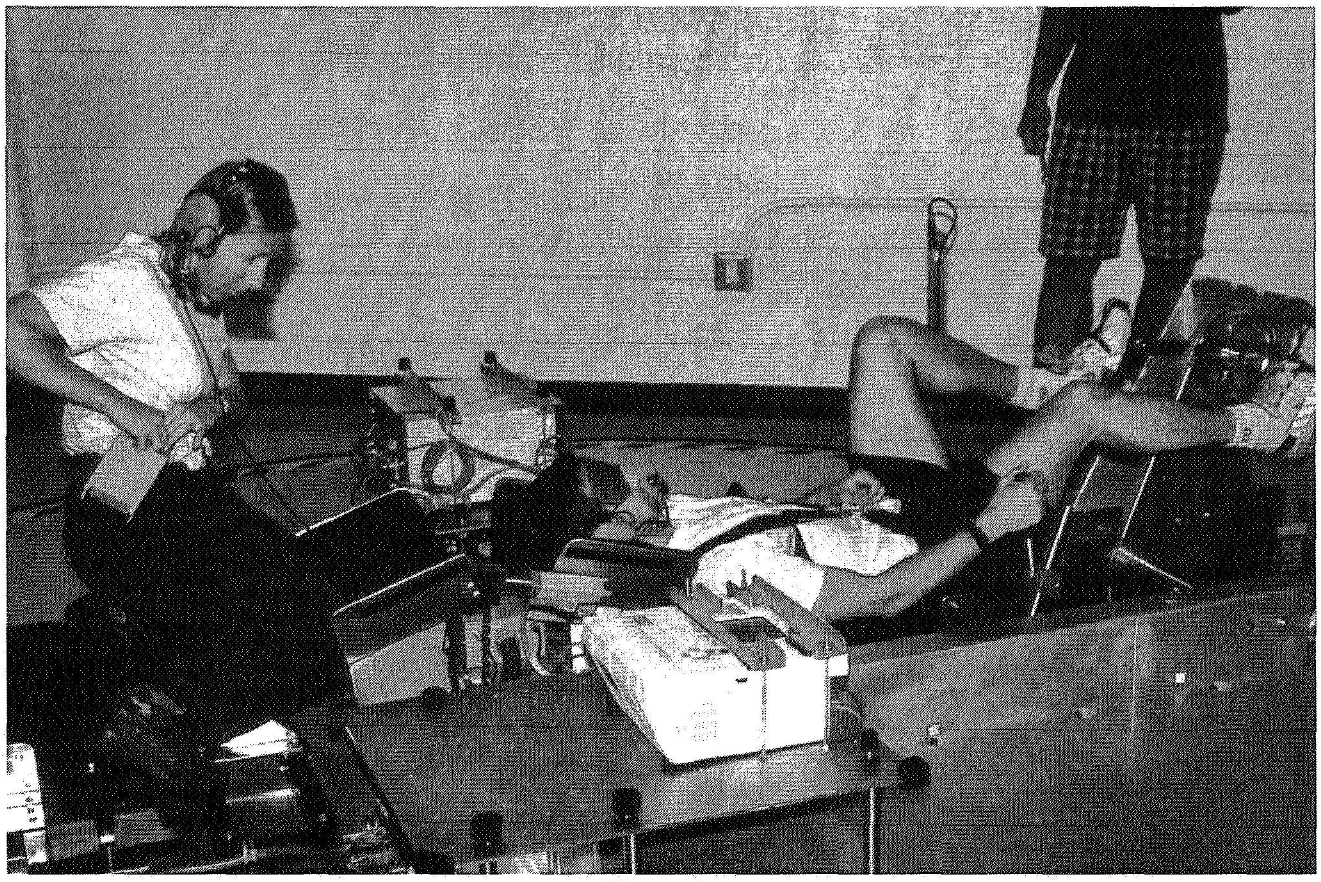


Figure 9.

rest, and then the maximal run (rpm) to volitional fatigue – followed by a cooling-down period (fig. 10, left panel). Then, after at least 3 days of recovery, the final maximal protocol (Part 2) was performed; it began with a 5-min warm-up period at about 40% of the maximal rpm (fig. 10, right panel). This was followed by 2 min at 60%, 2 min at 80%, and then increased by 20% of rpm-max•min^{-1} until volitional fatigue – followed by a 5-min cooling-down period. Because of the physical constraints of the couch on the 1.9-m centrifuge radius, all of the taller subjects commented about being cramped during exercise, and felt that it attenuated their performance.

Platform rpm (angular acceleration); that is, pedal cadence, was maintained with a digital tuner metronome (model DTM-12, Korg, Tokyo, Japan) through the subject's headset. Oxygen uptake, heart rate, ECG, RPE (modified Borg scale), and Gz level and platform rpm were recorded during all maximal acceleration protocols.

The CPX Express metabolic analyzer was calibrated by John Hoppe of Vacumetrics Inc./Vacu•Med Division. The difference between the CPX and Vacu•Med data are presented in appendix E. The mean respective O_2 and CO_2 differences were -1.13 and +0.09% (medium range) and -1.68 and +5.10% (high range).

<u>Tilt-table (orthostasis) protocol</u>. After one practice tilting without blood sampling, the experimental tilt test was conducted before and after each phase (fig. 3) with the subjects initially in the horizontal, supine body position (fig. 11) on the tilt table (Physical Therapy Treatment Table, Laberne Mfg. Co.,

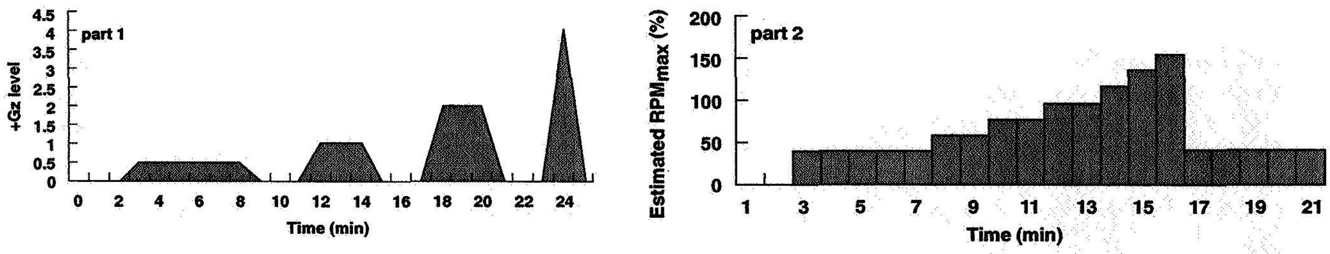


Figure 10.

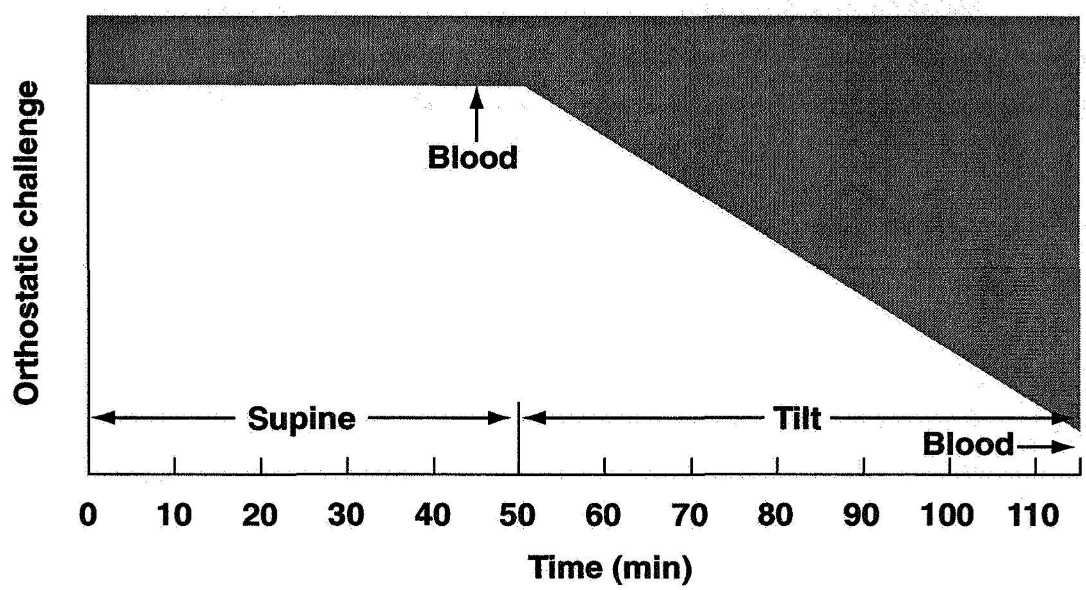


Figure 11.

Columbia, S.C.). After 35 min of supine rest (fig. 11), an 18-gauge Teflon catheter (Quick-Cath, Baxter Healthcare Corporation, Deerfield, Ill.) was inserted into the subject's right antecubital vein and 27 ml of blood collected for control measurements. Evans blue dye (T-1824: 2.5 ml, 25 mg•5 ml^{-1}, New World Trading Corporation, DeBary, Fla.) was then injected through the catheter for determination of resting plasma volume (PV); the catheter was subsequently flushed with saline (0.9% NaCl, McGaw, Inc., Irvine, Calif.). A venous blood sample (5 ml) was withdrawn at 10 min from the left arm and added carefully into a tube containing lithium-heparin. The table then was tilted to 70° head-up until the onset of pre-syncopal signs or symptoms such as a sudden decrease in systolic blood pressure > 25 mmHg•min^{-1}, decrease in diastolic blood pressure > 15 mmHg•min^{-1}, sudden drop in heart rate > 15 b•min^{-1}, accompanying nausea, clammy skin, perfuse sweating, or pallor. If none of these signs or symptoms was severe enough for termination, the test was stopped at 60 min. No subject reached unconsciousness. After only one $+Gz_{max}$ run subject RAY reported nausea, and subject SCH was dizzy, nauseated, and vomited after his run. Thus, both passive and active (exercise) acceleration resulted in far fewer adverse signs and symptoms than occurred after tilting (table 4).

Blood (23 ml) was collected from the catheter (after waste withdrawal) following return of the subjects to the supine position (fig. 11). About 480 ml of blood were taken over the 20-week study period. A 24-hr urine sample was collected just prior to each tilt test (fig. 3).

Table 4. Individual baseline (BL) and pre- and post-training pre-syncopal signs-symptoms (PS-S) and tilt time for the *three phases during tilt test.*

Phase I. Pre-Training (16 July) and Passive Training					
			Signs and symptoms	Tilt time, min	PS-S
FLE	No Tilt				
FRE	BL	16 July	OK	60	No
	Pre	10 Sept	OK	60	No
	Post	1 Oct	OK	60	No
HUN	BL	16 July	Tachycardia	60	No
	Pre	10 Sept	OK	60	No
	Post	1 Oct	OK	60	No
JAG	BL	16 July	Dizziness	23	Yes
	Pre	23 July	Light-headed	22	Yes
	Post	13 Aug	Strange feeling in head	27	Yes
RAY	BL	16 July	Cold sweat, dizzy, nausea	43	Yes
	Pre	23 July	Cold sweat, pale, nausea	32	Yes
	Post	13 Aug	OK	60	No
RUI	BL	16 July	Sweating, warm	60	Yes
	Pre	23 July	Pale, nervous	30	Yes
	Post	13 Aug	OK	60	No
SCH	BL	16 July	Can't relax, feet tingling	54	Yes
	Pre	10 Sept	Feet tingling, eye light flashing	59	Yes
	Post	1 Oct	OK	60	No

Phase II. Exercise Training					
FLE	No Tilt				
FRE	Pre	23 July	OK	60	No
	Post	13 Aug	OK	60	No
HUN	Pre	23 July	*Tachycardia*	60	No
	Post	13 Aug	OK	60	No
JAG	Pre	10 Sept	Very weak	46	Yes
	Post	1 Oct	Loss of vision	27	Yes
RAY	Pre	10 Sept	Nausea	48	Yes
	Post	1 Oct	OK	60	No
RUI	Pre	10 Sept	Can't relax	60	No
	Post	1 Oct	OK	60	No
SCH	Pre	23 July	Light-headed	51	Yes
	Post	13 Aug	Light-headed, facial muscle spasms	35	Yes

Table 4. Concluded.

Phase III. Combined Training					
FLE	29 Oct		OK	60	No
	19 Nov		OK	60	No
	17 Dec		OK	60	No
FRE	29 Oct		OK	60	No
	19 Nov		OK	60	No
	17 Dec		OK	60	No
HUN	29 Oct		BP fell dramatically	59	Yes
	19 Nov		BP fell dramatically	36	Yes
	17 Dec		OK	58	No
JAG	29 Oct		Light-headed, headache	27	Yes
	19 Nov		Nausea	19	Yes
	17 Dec		OK	28	No
RAY	29 Oct		Sweating, nausea	15	Yes
	19 Nov		Sweating, nausea	41	Yes
	17 Dec		OK	60	No
RUI	29 Oct		OK	60	No
	19 Nov		OK	60	No
	17 Dec		OK	60	No
SCH	No Tilt				

Physiological variables measured or calculated during the tilt test were heart rate from the ECG, thoracic impedance index, stroke volume (SV), and cardiac output ($\dot{Q}$, Cardiodynamic monitor, BoMed Medical Mfg., Ltd., Irvine, Calif.). Additional measurements that were monitored continuously included noninvasive arterial pressure (model 2300, Finapres Ohmeda, Englewood, Colo.; calibrated with a W.A. Baum Co., Inc. Baumanometer sphygmomanometer, Copiague, N.Y.), radial arterial blood flow (model 909, Parks Medical Electronic, Inc., Aloha, Oreg.), forearm skin perfusion (model PF4001, Perimed Periflux Smithtown, N.Y.), temple skin perfusion (model BPM 403A, LaserFlo Skin Perfusion Monitor, TSI, St. Paul, Minn.), and calf circumference with a sylastic strain gauge (model EC-4, D.E. Hokansen, Issaquah, Wash.); peripheral vascular resistance was calculated off-line from arterial pressure/cardiac output. All data were presented on a chart recorder (model MT 8800, Astro-Med, Inc., West Warwick, R.I.) and stored on an analog tape recorder (model MR-40, Teac, Japan) and in a computer (PC, Comteq Computer Co., Rockville, Md.; Windaq model DI-220, Dataq Instruments, Inc., Akron, Ohio) with a 250-Hz sampling rate.

Blood sampling and analyses. After whole blood was allocated for hematocrit (Hct) and hemoglobin concentration [Hb] analyses, the remaining blood was placed into chilled and treated tubes and centrifuged for 15 min at 1,500 G at 4°C – except growth hormone samples which were centrifuged for 20 min at 1,000 G (model RC2-B, Ivan Sorvall, Inc., Newton, Conn.). Hematocrit was measured immediately, while plasma for osmotic and Evans blue dye analyses was refrigerated at 4°C for analysis later that day. All other samples were stored at -70°C for analysis after the study. Tube treatment was potassium-EDTA plus 400 $IU \bullet mL^{-1}$ aprotinin for [Hb] and (PRA), [PVP], and [PA]; lithium-heparin for Hct, growth hormone (I-GH, B-GH, I-GF-1), and plasma osmotic, sodium,

potassium, albumin, and total protein concentrations; and EDTA plus reduced glutathione-saline-NaOH for [PE] and norepinephrine [PNE] concentrations.

Plasma volume was measured in supine subjects with the Evans blue dye technique from one 10-min post-injection blood sample (Campbell et al., 1958; Greenleaf et al., 1979). Syringes (Beckton-Dickenson, Franklin Lakes, N.J.) used for dye injection were weighed pre- and post- injection (model B6 balance, Mettler Instrument Corp., Highstown, N.J.) to determine the amount of dye injected. Blood was centrifuged for 15 min at 1,500 G (4°C) and the plasma eluate was analyzed from Sephadex columns (No. PD-10, Pharmacia LKB Biotechnology, Uppsala, Sweden) and measured at an absorbency of 615 nm (model 35 spectrophotometer, Beckman Instruments Inc., Irvine, Calif.).

Percent change in post-tilt PV was calculated from the Hct and [Hb] transformation equation (Greenleaf et al., 1979):

$$\%\Delta PV = \frac{100\,[Hb_B \times (1 - Hct_A \times 10^{-2})]}{[Hb_A \times (1 - Hct_B \times 10^{-2})]} - 100$$

where: B is before and A is after tilt.

This equation has been validated for a period of only 2 hr, but F-cell ratio errors should have been minimized (more equal distribution of red blood cells) with the subjects in the supine position before tilt testing. The post-tilt PV data were back-calculated to milliliters from percent changes calculated from the Hb-Hct transformation equation.

Hematocrit was measured in quadruplicate from microcapillary tubes, run for 10 min at 11,500 rpm on an International Equipment Company Micro-MB centrifuge (Needham Heights, Mass.), and read on a modified microcapillary tube reader (model CR Micro-capillary reader, International Equipment Company, Needham Heights, Mass.) sensitive to ± 0.1 Hct units. Raw Hct values were corrected for trapped plasma (0.96) and for whole body Hct (0.91). Blood [Hb] was measured in duplicate with a cyanomethemoglobin method (Sigma Diagnostics®, St. Louis, Mo.).

Plasma osmolality (± 1 mosmol•kgH_2O^{-1}) was determined by freezing-point depression (model 3R osmometer, Advanced Instruments, Needham Heights, Mass.). Plasma total protein, albumin, sodium, and potassium analyses variability (± SD, cv) of 10 runs on one sample were determined with a Beckman Coulter Synchron analyzer (model LX20, Beckman Coulter, Inc., Brea, Calif.): total protein (± 0.05 g•dL^{-1}, 1.0) with the biuret reaction (Kingsley, 1942), albumin (± 0.05 g•dL^{-1}, 1.5) with Bromecresol purple binding (Pinnell and Northam, 1978), and indirect potentiomentry (electrodes) for both sodium (± 0.05 mmol•l^{-1}, 0.4) and potassium (± 0.04 mmol•l^{-1}, 0.8) (Eisenman, 1967; Pioda et al., 1969).

Plasma hormone concentrations were analyzed by Helmut Hinghofer-Szalkay with radioimmunoassay, except the catacholamines which were analyzed by Michael Ziegler with the radioenzymatic method of Kennedy and Ziegler (1990). This modification of the catechol-o-methyltransferase (COMT)-based radioenzymatic assay for [PNE] and [PE] improves sensitivity and

selectivity, and eliminates many inhibitors of COMT. Prior to assay, the samples were extracted into heptane with diphenylborate and then put into dilute acetic acid. This extraction procedure has an efficiency of 78% for NE, but less than 2% for S-adenosylmethionine. The extraction procedure also excludes calcium and other COMT inhibitors present in urine, plasma, and every other tissue tested. This eliminated the requirement for individual standardization of tissue and urine samples. Sensitivity of the assay for PNE and PE in 1 ml of plasma was 10 and 6 pg•ml^{-1}, respectively. The respective intra-assay cv for PNE and PE were 4% and 13%, and the inter-assay cv for PNE and PE were 10% and 16%, respectively, in human plasma containing low catecholamine levels. The assay permits quantitation of PE levels that were undetectable in prior assays.

Plasma aldosterone was measured with a modified radioimmunoassay (AldoCTK-2, Sorin Biomedica, Italy); its sensitivity, defined as the apparent concentration of analyte that can be distinguished from the zero standard, was below 20 pg•ml^{-1} at the 95% confidence limit. The cv for the within- and between-assay variability was 9.7% and 11.5%, respectively. Plasma vasopressin was determined on ethanol-extracted plasma with a radioimmunoassay kit (Nichols Institue, Diagnostics BV, The Netherlands) with ^{125}I-AVP as the labeled compound. The anti-AVP antiserum did not cross-react with Lys^8-vasopressin, oxytocin, or vasotocin. Sensitivity at the 99% confidence limit was 1.3 pg•ml^{-1}. Plasma renin activity was determined by measurement of ANG-I (RENCTK, Sorin Biomedica, Italy) based on competition between labeled and native ANG-I to be assayed for a fixed number of antibody binding sites; PRA was expressed as nanograms of ANG-II formed per milliliter of plasma after 1 hr of incubation. Sensitivity was < 0.20 ng•ml^{-1} at the 95% confidence limit.

Plasma growth hormone [PGH] was measured by radioimmunoassay (RIA) and bioassay by Richard Grindeland. Eight-milliliter aliquots of blood, obtained before and after each experimental treatment, were put into 15-ml plastic centrifuge tubes containing 100 ul (100 units) of heparin, mixed gently, and placed in an ice bath. These tubes were then centrifuged at 1,000 G for 20 min at 5°C and the plasma transferred to cryovials for storage at -70°C. The frozen samples were thawed in a 37°C water bath, care being taken to not unduly heat the plasma. An aliquot of 0.5 – 1.0 ml of plasma was left in each tube for the immunoassay; the balance was pooled by experimental treatment, the volume measured, and the pooled samples put into siliconized vials until injected into bioassay rats. The plasma was bioassayed according to the procedure of Greenspan et al., (1949) in 40-day-old female albino rats which had been hypophysectomized at 26 days of age by the vendor (Hilltop Laboratories, Scottsdale, Pa.). After surgery the rats were allowed to recover for 3 days and were then shipped to Ames Research Center where they were inspected and allowed to acclimate to the new environment and diet and to regain their body water balance. The assay rats were weighed 7 and 14 days after surgery; animals that gained more than 1 g of body weight per day over that interval were considered incompletely hypophysectomized and were not used in the assay. Rats that lost more than 2 g total weight were also removed from the assay.

Five rats were put into each treatment group or dose level of standard hormone. Three dose levels (1, 5, and 15 µg total dose) of standard bovine GH (1.5 IU•mg^{-1}) were employed. Pooled plasma, standard, or saline was injected intraperitoneally (0.5 ml•day^{-1}) for 4 days; on the fifth day the rats were euthanized with an overdose of CO_2 and a tibia dissected out, split longitudinally, and stained with silver nitrate. The stained tibias were put into individual vials containing 70% ethanol until the proximal growth plates were read microscopically (Carl Zeiss, Germany) to the nearest micrometer. Ten readings of the epiphyseal plate thickness were made, averaged for each rat, then averaged by group, and then

compared to a standard curve derived from bovine growth hormone standards. Because of the limited volume of plasma, only a single dose level of plasma was used. The mean [PGH] and 95% confidence limits were calculated using a "bracketed three point assay" (Bliss, 1952). The [PGH] per milliliter of plasma was calculated as a function of the epiphyseal width. The bovine GH had a specific biological activity one half that of highly purified human GH, so values (ng•ml^{-1}) obtained from the standard curve were divided by 2 to yield human GH values. The commercial kits used for radioimmunoassays (Diagnostic Products, Inc. Los Angeles, Calif.) employed a double antibody system similar to the procedure of Utiger et al. (1962). Human growth hormone (hGH) standards (1-30 ng•ml^{-1}) or sample (100 µl) were pipetted into duplicate assay tubes. The standard hormone was NIH preparation NIAMDD hGH RP-1. Next, 100-µl aliquots of rabbit anti-human GH serum were added. The reagents were mixed on a vortex mixer and incubated for 1 hr at room temperature followed by addition of the radio-iodinated hGH, mixed again and incubated for another hour at room temperature. Then the cold second antibody (goat anti-rabbit gamma globulin) mixed with polyethylene glycol was added, the contents mixed, and the tubes centrifuged at 1,500 G for 30 min at 5°C. Except for one pair of tubes used to determine total counts, the supernatant was aspirated and the tubes were inverted to drain. The tubes were counted in a Packard Cobra model crystal scintillation counter for 1 min. After automatic subtraction of nonspecific binding, the results were plotted automatically as a log dose-logit curve and the results expressed as ng hGH•ml^{-1}. The interassay coefficient of variation was 5% and the intraassay coefficient was 4%; outlier samples were reassayed.

Urine collection and analyses. A 24-hr urine volume, collected just before each tilt test, was measured to ± 5 ml in a graduated cylinder and aliquots were frozen for subsequent analysis by Scott Smith. Urinary collagen cross-links (pyridinium, sensitivity 7.5 nmoles•l^{-1}) and deoxypyrodinoline (sensitivity 1.1 nmoles•l^{-1}) were determined with the Pyrilinks™ and Pyrilinks-D™ kits, respectively (Metra Biosystems, Palo Alto, Calif.). Concentrations of n-telopeptide were measured with the Osteomark® ELISA kit (Ostex International, Seattle, Wash.) which detects the n-telopeptide region of bone collagen specifically in human urine (Smith et al., 1998, 1999) with a sensitivity of 20 nmoles•l^{-1}. Hydroxyproline analysis was performed on an amino acid analyzer (model L-8800, Hitachi Corp., San Jose, Calif.) using methods adapted from Paroni et al. (1992) and Slocum and Cummings (1990). Urine samples and internal standard (glucosaminic acid, TCI America, Portland, Oreg.) were hydrolyzed in 6N HCl for 16 hr at 110°C. The hydrolysate was adjusted to a pH of 2.2 and concentrated using a Speedvac (Savant Corp., Holbrook, N.Y.). The solution was filtered through a 0.2-µm filter and brought to volume with lithium buffer solution (pH 2.2). The protein-free filtrate was refrigerated until injected onto the analyzer. Post-column ninhydrin derivatization produces a chromagen detectable at 440 nm with a sensitivity of 0.021 µmoles•ml^{-1}. Urinary calcium was determined using an atomic absorption spectrophotometer (model 4000, Perkin-Elmer, Norwalk, Mass., with a sensitivity of 5 mg•dl^{-1}). Creatinine was also determined spectrophotometrically (Owen et al., 1954) with a sensitivity of 0.1 mg•dl^{-1}.

Magnetic Resonance Imaging (MRI). The lower body of each subject was imaged 2 days before and 1 day after completion of each of the 3-week training regimens on a 1.5 Tesla whole-body MR imager (Siemens Vision™, Iselin, N.J.) at Los Gatos MRI (Los Gatos, Calif.) by Peter Hardy. The subjects were supine with their feet at the center of the imaging magnet; their thighs were imaged by the body coil of the imager. Three types of images were obtained during each session: (1) 1-cm-thick T1-weighted images of the pelvis and thighs to estimate the volume of the rectus femoris, vastus lateralis, vastus intermedius, and vastus medialis; (2) a flow-alternating inversion recovery (FAIR) image

estimated perfusion of the quadriceps muscle; and (3) a multi-echo technique measured the spin-spin relaxation time (T2); that is, values proportional to the amount of work a muscle performs. The multi-echo spin images (T2) were calculated pixel-by-pixel for each of the five slices acquired through the thighs. The IDL software allowed the user to select an arbitrarily defined region in the muscle from which to obtain basic statistics such as average and standard deviation over the region. The average T2 in each head of the quadriceps muscle was extracted from the images taken before and after the subjects did a maximal number of deep knee bends. The change in T2 ($T2_{post} - T2_{pre}$) was calculated for a given muscle.

Total imaging time was approximately 45 min. The MR images were transferred onto magneto-optical disks for analysis at the University of Kentucky. The volumes of the four heads of the quadriceps muscle in each leg were determined by manually outlining the muscles using the commercially available image analysis software 3DVIEWNIX. Total muscle volume was the sum of the areas outlined on each image multiplied by the slice-to-slice separation.

The T2 data were determined from the multi-echo images, using user-derived software, and perfusion data were derived from the FAIR images, using custom software written in IDL.

DATA ANALYSIS

Hemodynamic. A data analysis system devised by David Brown was developed for the Intel Windows platform using Microsoft Visual C. Analysis routines were designed to organize, group, scan, and average a large number of data sets to provide quick and easy access to signal processing, and to statistical and data base functions. A data collection system was developed using the Intel Windows platform and Microsoft Visual C++. Data acquisition used National Instruments E-series analog-to-digital converters and a full-screen high-performance mode to sample and display continuously up to 16 channels of data at sample rates from 1 to 10,000 Hz (or higher depending on the AD board).

All digitally sampled (250-Hz) wave forms (arterial pressure, peripheral flows, respiration, etc.) were analyzed to give both integrated mean values as well as spectral power results using the data analysis system described above. After R-wave detection, instantaneous R-R interval time series were constructed from the ECG. The resulting piecewise constant time series was low-pass filtered and sampled at 5 Hz. Auto- and cross-spectral estimates were computed using averaged periodograms. A Hanning window was used to reduce side-lobe error. Estimates of coherence were computed as a ratio of the squared magnitude of the cross spectrum divided by the product of the two autospectra. For each variable, the 10 min of resting control and 60 min of tilt data were divided into 200-sec segments for analysis. Mean values and spectral power from each rest and control period were averaged within subjects to enhance robustness. Results were then averaged across subjects for plotting and statistical analysis.

Statistical. Means and standard deviations (± SD) were calculated for subject characteristics, and means and standard errors (± SE) were calculated for all other variables. The exercise, tilt, and blood variables were analyzed with a three-factor analysis of variance (SPSS 7.5 for Windows; SPSS, Inc., 1996, Chicago, Ill.) with significant differences between the means determined with the Dunnett post-

hoc procedure. In addition, mean values and spectral power of the hemodynamic data were analyzed using a three-factor ANOVA (PC SAS version 6.12, SAS Institute, Inc., Cary, N.C.) to assess the significance of main effects: training protocols and tilting before and after training. When post-hoc testing was warranted (significant F-ratio for the effect of interest), t-statistics with degrees of freedom determined by Satherwaite's approximation, were constructed to compare mean responses. In all cases statistical significance was determined at $P < 0.05$ and nonsignificant changes were NS.

RESULTS

Maximal Exercise (Passive, Exercise, Combined) Data

Exercise load. The maximal exercise loads were increased ($P < 0.05$) for all three Phases after training (fig. 12a) in stepwise order from Passive (by $8.3 \pm 4.3\%$), to Exercise (by $12.6 \pm 5.7\%$), to Combined (by $15.4 \pm 2.6\%$) (fig. 12b).

Oxygen uptake. However, maximal oxygen uptake tended to decrease (NS) with Passive training and to increase (NS) with Exercise and Combined training (figs. 13a and 13b).

Heart rate. Maximal exercise heart rates (HR_{max}) were decreased by $3 \pm 2\%$ (NS) with Passive, unchanged ($0 \pm 2\%$) with Exercise, and tended to increase by $2 \pm 2\%$ (NS) with Combined training (figs. 14a and 14b).

Exercise tolerance. Maximal exercise time to fatigue was unchanged ($+2.6 \pm 3.4\%$, NS) with Passive, but was increased by $6.0 \pm 4.9\%$ ($P < 0.05$) with Exercise, and by $17.9 \pm 3.2\%$ ($P < 0.05$) with Combined training (figs. 15a and 15b).

Orthostatic (Tilt-Table) Cardiovascular Data

Resting pre-tilt heart rate. Resting HR (mean of 2 min before tilting) was unchanged with the three training Phases (fig. 16a), but was elevated by $12.9 \pm 5.2\%$ ($P < 0.05$) after Passive training (fig. 16b).

Resting pre-tilt systolic blood pressure. Mean resting SBP was unchanged after training in each of the respective Phases (fig. 17a). However, it tended to increase (NS) with Passive and decrease (NS) with Exercise and Combined Phases (fig. 17b).

Resting pre-tilt diastolic blood pressure. Mean resting DBP was also unchanged after training in each of the respective Phases (fig. 18a), and it also tended to be lower (NS) with Exercise and Combined Phases (fig. 18b).

Resting pre-tilt mean arterial pressure. Average MAP followed the SBP and DBP with a tendency to increase (NS) with Exercise and Combined Phases (figs. 19a and 19b).

Tilt-tolerance time. Mean tilt-tolerance time pre- to post-training was increased only with Passive training from 43.5 ± 7.2 to 54.7 ± 5.3 min, respectively (fig. 20a); that is, by 37.8 ± 19.6% ($P < 0.05$) (fig. 20b); tolerances were unchanged with the Exercise and Combined Phases.

Heart rate at tolerance. Mean HR at tolerance pre- to post-training was increased from 71 ± 8 to 89 ± 7 bpm, respectively (fig. 21a); that is, by 29.1 ± 7.7% ($P < 0.05$) with Passive training; HR was unchanged with the Exercise and Combined Phases.

Mean arterial pressure at tolerance. Average MAP at tolerance was increased from 88 ± 13 to 108 ± 10 mmHg (by 33.4 ± 18.8%, $P < 0.05$) with Passive, and from 78 ± 9 to 96 ± 6 mmHg (by 28.8 ± 14.7%, $P < 0.05$) with Combined; Exercise MAP was unchanged (figs. 22a and 22b).

Cardiac R-R interval with training. R-R intervals were not different at rest for the six treatments pre- and post-tilt for the three Phases (fig. 23). The greater the R-R interval, the slower the HR. But the intervals were uniformly lower ($P < 0.05$) for the six post-tilt treatments with no differences between or among Phases.

Stroke volume with training. Stroke volume, similar to the R-R interval, was not different at rest for the six treatments for the three Phases (fig. 24), but it was uniformly lower ($P < 0.05$) at about 60 ml•beat^{-1} for the six post-tilt treatments with no differences between or among Phases.

End-diastolic volume with training. E-D volume was not different at rest for the six treatments for the three Phases (fig. 25) but it was also uniformly decreased ($P < 0.05$) for the six post-tilt treatments with no differences between or among Phases.

Cardiac output with training. Cardiac ouput was not different at rest for the six treatments for the three Phases (fig. 26), and $\dot{Q}$ was uniformly decreased ($P < 0.05$) for the six post-tilt treatments with no differences between or among Phases.

Cuff arterial pressure with training. Arterial pressure was not different at rest or post-tilt for the six respective treatments for the three Phases (fig. 27). But all post-tilt values tended (NS) to be higher than their corresponding rest values.

Total peripheral resistance with training. Total PR was not different at rest for the six treatments for the three Phases (fig. 28). But PR was uniformly increased ($P < 0.05$) for the six post-tilt treatments with no differences between or among Phases.

Cardiovascular variables. (figs. 29a and 29b).

Blood hemoglobin [Hb]. Hemoglobin concentration was not different at rest for the six treatments or at post-tilt for the six treatments in the three Phases (fig. 30a). But Hb post-tilt was increased ($P < 0.05$) for five treatments (except for post-Combined) reflecting decreases in plasma volume post-tilt. This is also indicated in the percent changes in Hb at rest and post-tilt (fig. 30b). Percent changes in Hb at tilt tolerance pre- and post-training (fig. 30c) indicate significant ($P < 0.05$) increases in five treatments–except for post-training in the Combined Phase.

Raw hematocrit (Hct). Hematocrit was not different at rest for the six treatments or at post-tilt for the six treatments in the three Phases (fig. 31a). But Hct was uniformly increased ($P < 0.05$) for the six post-tilt treatments (reflecting decreases in plasma volume) with no differences between or among Phases. This also reflected decreases in plasma volume post-tilt that are reflected in the percent changes in Hct at rest and post-tilt (fig. 31b). Percent changes in Hct at tilt tolerance pre-and post-training indicated significant ($P < 0.05$) increases in all six treatments (fig. 31c).

Plasma volume (PV). Measured (T-1824) PV was not different at rest or post-tilt for the six treatments in the three Phases (fig. 32a). But PV was uniformly decreased ($P < 0.05$) for five treatments–except for post-training in the Combined Phase. These results are also indicated in the percent changes in Hct at rest and post-tilt (fig. 32b). Percent changes in PV at tilt-tolerance pre-and post-training (fig. 32c) indicate significant ($P < 0.05$) decreases for five treatments–except for post-training in the Combined Phase.

Plasma sodium [PNa]. Plasma sodium concentration varied between 136 and 138 $mmol \bullet l^{-1}$ with post-tilt levels generally lower than comparable rest (pre-tilt) values, except for Exercise post-training (fig. 33a). Percent changes in [PNa] at rest and post-tilt (fig. 33b) were uniformly higher with Passive and Exercise Phases, when compared with essentially unchanged Combined data. Conversely, all percent changes in [PNa] at tolerance pre-and post-training were negative and varied form 0.4 to 0.8 (all NS). Sodium accompanied the vascular-to-interstitial-fluid space shift of PV, so [PNa] remained unchanged.

Plasma potassium [PK]. Plasma potassium concentration varied between 3.9 and 4.3 $mmol \bullet l^{-1}$ at rest and post-tilt (fig. 34a), with reduced percent change at rest and post-tilt for the three Phases except for Exercise post-tilt (fig. 34b). Percent changes at tolerance with training were positive (NS) with Passive and Exercise and negative (NS) with Combined Phases; the greatest post-training increase in [PK] was with Exercise and the greatest decrease with Combine (fig. 34c).

Plasma osmolality [POsm]. Plasma osmotic concentration varied between 286 and 289 $mOsm \bullet kg^{-1}$ at rest and post-tilt with somewhat lower (NS) values post-tilt, except for Combined (fig. 35a). There were greater percent changes with training in Passive and Exercise, and the lower changes with Combined (fig. 35b) were qualitatively similar with comparable [PNa] responses. There was a minimal percent change in [POsm] with training at tilt-tolerance (fig. 35c) which was similar to comparable [PNa] changes in response to outward shifts of PV. Percent changes in [POsm] were in the same negative direction but were much smaller than comparable [PNa] shifts, and [PK] tended to increase.

Plasma albumin [PAlb]. Plasma albumin concentration was increased (most $P < 0.05$) post-tilt pre- and post-training (fig. 36a). It tended to decrease (NS) at rest and post-tilt with training with Passive and Exercise, but to increase (NS) with Combined (fig. 36b). All percent changes at tolerance pre-and post-training were uniformly positive (range 5.1% to 9.1%), some significantly increased from zero, with no difference among them (fig. 36c). These increases in [PAlb] reflect losses (shifts) in PV.

Plasma total protein [PTP]. Plasma total protein concentration responses were qualitatively similar to those of [PAlb]: compare figures 36b and 37b, and 36c and 37c.

Plasma renin activity (PRA). Renin activity was not different at rest pre-and post-training and varied within the normal range; our data were 0.45 to 0.77 ngAngI•ml^{-1}•hr^{-1} but all PRA were elevated ($P < 0.05$) post-tilt within the range of 1.51 to 2.47 ngAngI•ml^{-1}• hr^{-1} (fig. 38a). The percent change in both PRA's decreased (NS) with Passive, increased (NS) with Exercise, and were unchanged with Combined (fig. 38b). All percent changes in PRA at tolerance pre-and post-training were increased ($P < 0.05$) by 181% to 351% (fig. 38c).

Plasma aldosterone [PA]. In general, the [PA] responses were similar, as expected, to those of PRA. The rest [PA] were not different and were within the normal range; our data were 72 to 115 pg•ml^{-1} (fig. 39a); but all [PA] values were elevated ($P < 0.05$) post-tilt within the range of 238 to 276 pg•ml^{-1}. Percent changes in rest [PA] decreased by 29% (NS) with Passive but increased by 95% (NS) with Exercise; post-tilt [PA] were unremarkable (+0.7% and +20.5%, respectively) (fig. 39b). All percent changes in [PA] at tolerance pre-and post-training were increased by 67% to 451% in the Passive and Exercise Phases (fig. 39c) similar to comparable PRA data in fig. 38c.

Plasma vasopressin [PVP]. Plasma vasopressin concentration at rest was at the high end of normal or higher with a range of 1.4 to 6.7 pg•ml^{-1} (fig. 40a). The resting Combined [PVP] were especially elevated at 6.7 and 4.0 pg•ml^{-1}, respectively, post-tilt levels were greatly elevated with Passive (72.7 pre vs. 34.2 pg•ml^{-1} post) and Exercise (35.0 pre vs. 28.1 pg•ml^{-1} post). Percent changes in [PVP] at rest and post-tilt with training varied considerably from -13.2% Combined post-tilt to 259.9% Exercise rest (fig. 40b). However, the percent changes in [PVP] at tilt-tolerance pre-and post-training were most diverse: the increases were about 10,000% with pre-and post-training Passive and pre-training Exercise; the other three varied form 83% to 957% (fig. 40c).

Plasma epinephrine [PE]. Plasma epinephrine concentration at rest was essentially unchanged among the six treatments; they varied from 25 to 31 pg•ml^{-1} (fig. 41a). Post-tilt levels (except for Combined post-training) tended to be elevated (NS) from 47 to 106 pg•ml^{-1}. At rest the percent changes in [PE] pre- versus post-training were all positive for the three Phases, but all were negative post-tilt (fig. 41b). All percent changes in [PE] at tilt-tolerance pre-training and post-training (except Combined) were positive (range 80% to 268%) (fig. 41c).

Plasma norepinephrine [PNE]. Plasma norepinephrine concentration at rest was also essentially unchanged among those six treatments; they varied from 199 to 258 pg•ml^{-1} (fig. 42a). All post-tilt levels were elevated ($P < 0.05$) from rest levels (range 381 to 581 pg•ml^{-1}). Percent changes pre-training versus post-training at rest and post-tilt varied within ± 20% (fig. 42b). All percent changes in [PNE] at tilt-tolerance for the three Phases were increased ($P < 0.05$) by 90% to 132%; there were no differences among those six treatments (fig. 42c).

Plasma dopamine [PD]. Plasma dopamine concentrations at rest and post-tilt were variable but not significantly different among the six treatments (fig. 43a). Percent changes in [PD] post-tilt were attenuated compared to rest pre-training versus post-training for the three Phases (fig. 43b), and there were similar responses at tilt-tolerance pre- and post-training (fig. 43c).

Plasma growth hormone [PGH]. Plasma growth hormone concentration as measured by radioimmunoassay (RIA), with two exceptions, was essentially undetectable (value = 1) in the pre-

Phase resting periods (fig. 44a). At post-tilt it varied from 2.2 ± SE 1.1 ng•ml^{-1} (pre-Combined) to 10.0 ± 4.1 ng•ml^{-1} with pre-Passive. Summed post-tilt levels were highest with Passive (10.0 + 4.5), somewhat lower with Exercise (3.7 + 5.4), and lowest with Combined (3.3 + 2.2) suggesting progressively less respective stress during tilting. Of the 16 cases (excluding baseline data) in Table 4 who experienced post-training pre-syncopal signs and symptoms (PS-S), 13 had increased (greater than 1) [PGH]; but there were 10 cases with increased [PGH] that did not have PS-S. Thus, onset of PS-S was minimally associated with increased [PGH].

From bioassay data, the resting levels (with two exceptions of 1375 and 1205) ranged from 720 to 775 ng HGH•ml^{-1} (fig. 44b). However, unlike the RIA findings, the summed post-tilt data were highest with Combined (2075 + 2000 = 4075), somewhat lower but similar with the Exercise (775 + 1850 = 2625) and Passive (2125 + 575 = 2700) Phases. Most individual Phase resting versus post-tilt values were significantly different except for post-Passive and pre-Exercise training. Clearly there are great individual differences in [PGH] after tilt that do not appear to be associated with pre-syncopal signs or symptoms.

In like manner, about half of the post-exercise [PGH] were greater that 1 before and after Combined training (see PGH table in appendix F).

Urine Data (24 hr)

Urinary volume and rate (24 hr). Urinary 24-hr volumes were not different between and among pre- and post-training samples for the three Phases (fig. 45). All urinary excretion rates (milliliters per minute) were within normal limits for uncontrolled food and fluid intakes.

Urinary variables: The urinary variables were creatinine (fig. 46), deoxypyridinoline (fig. 47), deoxypyridinoline / creatinine ratio (fig. 48), n-telopeptide (fig. 49), n-telopeptide / creatinine ratio (fig. 50), pyridinium cross-links (fig. 51), pyridinium cross-links / creatinine ratio (fig. 52), hydroxyproline (fig. 53), hydroxyproline / creatinine ratio (fig. 54), and calcium (fig. 55). There were no significant differences between or among these 24-hr urinary variables pre- or post-training for the three Phases; it is noted that the 24-hr sampling time may have been too short.

Magnetic Resonance Imaging

Volume. There was a significant ($P < 0.05$) increase of 4% to 6% in all four quadriceps muscle volumes (T1), both right and left, post-Combined training (fig. 56).

Excitation. Change in the multi-echo spin images (T2, excitation) of their muscles during pre-Combined training was correlated 0.79 ($r^2 = 0.62$) with the number of knee bends, that is, the amount of muscular work (fig. 57). Each subject performed different numbers of knee bends according to his maximal ability.

SUMMARY OF RESULTS

Maximal Exercise (Passive, Exercise, Combined) Data

1. Maximal supine exercise loads increased significantly ($P < 0.05$) by 8.3% (Passive), by 12.6% (Exercise), and by 15.4% (Combined) after training, but their post-training maximal oxygen uptakes and maximal heart rates were unchanged. Maximal time to fatigue (endurance) was unchanged with Passive, but it too increased ($P < 0.05$) with Exercise and Combined training. Thus, the exercise in the Exercise and Combined training Phases resulted in greater maximal loads and endurance without effect on maximal oxygen uptake or heart rate.

Orthostatic (Tilt-Table) Cardiovascular Data

1. Resting pre-tilt heart rate was elevated by 12.9% ($P < 0.05$) only after Passive training, suggesting that the exercise training attenuated the HR response. Resting pre-tilt blood pressures (SBR, DBP, MAP) were not different pre- or post-training in any Phase. Post-training tilt-tolerance time and heart rate were increased ($P < 0.05$) only with Passive training by 37.8% and by 29.1%, respectively. Thus, addition of exercise training appeared to attenuate the increased Passive tolerance.

2. Resting (pre-tilt) and post-tilt cardiac R-R interval, stroke volume, end-diastolic volume, and cardiac output were all uniformly reduced ($P < 0.05$), and peripheral resistances were uniformly increased ($P < 0.05$) pre- and post-training for the three Phases, indicating there was no effect of the exercise training on these cardiovascular variables.

Othostatic (Tilt-Table) Biochemical Data

1. Plasma volume (percent change) was uniformly decreased by 8% to 14% ($P < 0.05$) at tilt-tolerance pre-training versus post-training, indicating essentially no effect of training on the level of hypovolemia. The latter was reflected in the 6% to 12% ($P < 0.05$) increase in [PAlb] and [PTP].

2. Percent changes in [PNa] pre-training versus post-training were minimal (less than -0.8%) as was [POsm] (less than -0.4%) indicating that plasma shifts during tilting were essentially isotonic.

3. The percent changes in [PRA], [PA], [PE], and [PNa] exhibited similar characteristic increases at tolerance both pre- and post-training, whereas the usual increase in [PVP] was greatly attenuated post-training with Exercise, and pre- and post-training with Combined. The explanation for the latter is not obvious but is not likely a result of technical errors.

Urine Data (24 hr)

1. Urinary volumes were within normal limits (1.2 to 1.5 $ml \bullet min^{-1}$) between and among pre- and post-training samples for the three Phases.

2. There were no significant differences between or among the 10 urinary variables pre- and post-training for the three Phases.

Magnetic Resonance Imagining

1. There was a 4% to 6% increase ($P < 0.05$) in all four quadriceps muscle volumes (right and left) after post-Combined training.

REFERENCES

Bliss, C.I. The Statistics of Bioassay, with Special Reference to the Vitamins. New York: Academic Press, 1952. p. 480-525.

Borg, G.A.V. Psychophysical bases of perceived exertion. Med Sci Sports Exerc 14:377-381, 1982.

Buckey, J.C., Jr, L.D. Lane, B.D. Levine, D.E. Watenpaugh, S.J. Wright, W.E. Moore, F.A. Gaffney, and C.G. Blomqvist. Orthostatic intolerance after spaceflight. J Appl Physiol 81:7-18, 1996.

Burton, R.R. A human-use centrifuge for space stations: proposed ground-based studies. Aviat Space Environ Med 59:579-582, 1988.

Campbell, T.J., B. Frohman, and E.B. Reeve. A simple, rapid, and accurate method of extracting T-1824 from plasma, adapted to the routine measurement of blood volume. J Lab Clin Med 52:768-777, 1958.

Chou, J.L. Human Physiological Responses during +Gz Acceleration with Cycle Ergometer Leg Exercise. San Francisco State University; M.A. thesis in Biology: Physiology and Behavioral Biology, 1997. 43p.

Chou, J.L., G.P.N. Leftheriotis, N.J. Stad, N.F. Arndt, C.G.R. Jackson, S. Simonson, P.R. Barnes, and J.E. Greenleaf. Human physiological responses to cycle ergometer leg exercise during +Gz acceleration. Ames Research Center, Moffett Field, CA: NASA Tech Memo –1998 – 112237. 22p.

Chou, J.L., M.A. McKenzie, N.J. Stad, P.R. Barnes, C.G.R. Jackson, F. Ghiasvand, and J.E. Greenleaf. Acceleration tolerance: Effect of exercise, acceleration training; bed rest and weightlessness deconditioning. A compendium of research (1950-1996). Ames Research Center, Moffett Field, CA: NASA Tech Memo 112214, 1997. 52p.

Collins, J.J. , C.J. DeLuca, A.E. Pavlik, S.H. Roy, and M.S. Emley. The effects of spaceflight on open-loop and closed-loop postural control mechanisms: human neurovestibular studies on SLS-2. Exp Brain Res 107:145-150, 1995.

Convertino, V.A. Physiological adaptations to weightlessness: Effects on exercise and work performance. Exerc Sport Sci Rev 18:119-166, 1990.

Eisenman, G. Glass Electrodes for Hydrogen and Other Cations: Principles and Practice. New York: Marcel Dekker, Inc, 1967. 582p.

Ellis, S., L.C. Kirby, and J.E. Greenleaf. Lower extremity muscle thickness during 30-day 6° head-down bed rest with isotonic and isokinetic exercise training. Aviat Space Environ Med 64:1011-1015, 1993.

Greenleaf, J.E., E.M. Bernauer, A.C. Ertl, R. Bulbulian, and M. Bond. Isokinetic strength and endurance during 30-day 6° head-down bed rest with isotonic and isokinetic exercise training. Aviat Space Environ Med 65:45-50, 1994.

Greenleaf, J.E., E.M. Bernauer, A.C. Ertl, T.S. Trowbridge, and C.E. Wade. Work capacity during 30 days of bed rest with isotonic and isokinetic exercise training. J Appl Physiol 67:1820-1826, 1989.

Greenleaf, J.E., J.L. Chou, N.J. Stad, G.P.N. Leftheriotis, N.F. Arndt, C.G.R. Jackson, S.R. Simonson, and P.R. Barnes. Short-arm (1.9 m) +2.2 Gz acceleration: isotonic exercise load-O_2 uptake relationship. Aviat Space Environ Med 70:1173-1182, 1999.

Greenleaf, J.E., V.A. Convertino, and G.R. Mangseth. Plasma volume during stress in man: osmolality and red cell volume. J Appl Physiol 47:1031-1038, 1979.

Greenleaf, J.E., D.P. Gundo, D.E. Watenpaugh, G.M. Mulenburg, M.A. McKenzie, R. Looft-Wilson, and A.R. Hargens. Cycle-powered short radius (1.9 m) centrifuge: Effect of exercise versus passive acceleration on heart rate in humans. Ames Research Center, Moffett Field, CA: NASA Tech Memo 110433, 1997. 10p.

Greenspan, F.X., C.H. Li, M.E. Simpson, and H.M. Evans. Bioassay of hypophyseal growth hormone: tibia test. Endocrinology 45:455-463, 1949.

Kakurin, L.I., B.S. Katkovskiy, V.A. Tishler, G.I. Kozyrevskaya, V.S. Shashkov, V.S. Georgiyevskiy, A.I. Grigoryev, V.M. Mikhaylov, O.D. Anashkin, G.V. Machinskiy, A.A. Savilov, and Ye.P. Tikhomirov. Substantiation of a set of preventive measures referable to the objectives of missions in the Salyut orbital station. Kosm Biol Aviakosm Med 12:20-27, 1978.

Kennedy, B., and M.G. Ziegler. A more sensitive and specific radioenzymatic assay for catecholamines. Life Sci 47:2143-2153, 1990.

Kingsley, G.R. Direct biuret method for determination of serum proteins as applied to photoelectric and visual colorimetry. J Lab Clin Med 27:840-845, 1942.

Kotovskaya, A.R., R.R. Galle, and A.A. Shipov. Biomedical research on the problem of artificial gravity. Kosm Biol Aviakosm Med 11:12-19, 1977.

LeBlanc, A.D., V.S. Schneider, H.J. Evans, D.A. Engelbretson, and J.M. Krebs. Bone mineral loss and recovery after 17 weeks of bed rest. J Bone Miner Res 5:843-850, 1990.

LeBlanc, A., V. Schneider, L Shackelford, S. West, V.Oganov, A. Bakulin, and L. Veronin. Bone mineral and lean tissue loss after long duration spaceflight. J Bone Miner Res 11:S323, 1996.

Mulenburg, G.M., and J. Vernikos. Human powered centrifuge. US Patent 5,616,104, April, 1997.

Nicogossian, A.E. Overall physiological response to space flight. In: Space Physiology and Medicine (2nd ed.), edited by A.E. Nicogossian, C.L. Huntoon, and S.L. Pool. Philadelphia: Lea and Febiger, 1994. p. 139-153.

Owen, J.A., B. Iggo, F.J. Scandrett, and C.P. Stewart. The determination of creatinine in plasma or serum, and in urine; a critical examination. Biochem J 58:426-437, 1954.

Paloski, W.H., M.F. Reschke, F.O. Black, D.D. Doxey, and D.L. Harm. Recovery of postural equilibrium control following spaceflight. Ann NY Acad Sci 656:747-754, 1992.

Paroni, R., E. De Vecchi, I. Fermo, C. Arcelloni, L. Diomede, F. Magni, and P.A. Bonini. Total urinary hydroxyproline determined with rapid and simple high-performance liquid chromatography. Clin Chem 38:407-411, 1992.

Pinnell, A.E., and B.E. Northam. New automated dye-binding method for serum albumin determination with bromcresol purple. Clin Chem 24:80-86, 1978.

Pioda, L.A.R., V. Stankova, and W. Simon. Highly selective potassium ion responsive liquid-membrane electrode. Anal Lett 2:665-674, 1969.

Shulzhenko, E.B., I.F. Vil-Vilyams, E.A. Aleksandrova, and K.I. Gogolev. Prophylatic effects of intermittent acceleration against physiological deconditioning in simulated weightlessness. Life Sci Space Res 17:187-192, 1979.

Shulzhenko, E.B., I.F. Vil-Vilyams, M.A. Khudyakova, and A.I. Grigoryev. Deconditioning during prolonged immersion and possible countermeasures. Life Sci Space Res 14:289-294, 1976.

Slocum, R.H., and J.G. Cummings. Amino acid analysis of physiological samples. In : Techniques in Diagnostic Human Biochemical Genetics, edited by F.A. Hommes. New York: Wiley-Liss, 1990. p. 87-126.

Smith S.M., J.L. Nillen, A. LeBlanc, A. Lipton, L.M. Demers, H.W. Lane, and C.S. Leach. Collagen cross-link excretion during space flight and bed rest. J Clin Endocrinol Metab 83:3584-3591, 1998.

Smith, S.M., M.E. Wastney, B.V. Morukov, I.M. Larina, L.E. Nyquist, S.A. Abrams, E.N. Taran, C.-Y. Shih, J.L. Nillen, J.E. Davis-Street, B.L. Rice, and H.W. Lane. Calcium metabolism before, during, and after a 3-mo spaceflight: kinetic and biochemical changes. Am J Physiol Regulatory Integrative Comp Physiol 277:R1-R10, 1999.

Sonnenfeld, G. Immune responses in space flight. Int J Sports Med 19 (Suppl 3):S195-S204, 1998.

Stad, N.J. Exercise-Induced +Gz Acceleration versus Exercise and Acceleration: Effect on Aerobic Work Metabolism. San Francisco State University; M.A. thesis in Biology: Physiology and Behavioral Biology, 1998. 56p.

Stone, R.W., Jr., W. Letko, and W.R. Hook. Examination of a possible flight experiment to evaluate an onboard centrifuge as a therapeutic device. In: The Role of the Vestibular Organs in Space Exploration, edited by J. Huertas, and A. Graybiel. Washington, DC: NASA Special Publ 115, 1966. p. 245-256.

Utiger, R.D., M.L. Parker, and W.H. Daughaday. Studies on human growth hormone. I. A radio-immunoassay for human growth hormone. J Clin Invest 41:254-261, 1962.

Vener, J.M. Cardiopulmonary Responses to Incremental Supine Cycle Ergometry with Concomitant +Gz Acceleration. California State University, Fresno; M.A. thesis in Kinesiology, 2000. 92p.

Vernikos, J. Artificial gravity intermittent centrifugation as a space flight countermeasure. J Gravit Physiol 4:P13-P16, 1997.

Vil-Viliams, I.F. Principle approaches to selection of the short-arm centrifuge regimens for extended space flight. Acta Astronautica 33:221-229, 1994.

Vil-Vilyams, I.F., and Ye.B. Shulzhenko. Functional state of the cardiovascular system under the combined effect of 28-day immersion, rotation on a short-arm centrifuge and exercise on a bicycle ergometer. Kosm Biol Aviakosm Med 14:42-45, 1980.

White, P.D., J.W. Nyberg, L.M. Finney, and W.J. White. Influence of periodic centrifugation on cardiovascular functions of man during bed rest. Santa Monica, CA: Douglas Aircraft Co., Inc., Rept No DAC-59286, 1966. 47p.

Zerath, E. Effects of microgravity on bone and calcium homeostasis. Adv Space Res 21:1049-1058, 1998.

Figure 12. The Ames HPC-99 Research Team. (left to right) John Greenleaf, Jon Griffith, Jamie Vener, Heather Wilson, James Klem, Kendra Bailey-Pemberton, Jodie Stocks, Stephenie Cowell, Simon Evetts, Paul Barnes, Shawn Simonson, Sunitra Shastry.

Present Addresses:

S.A. Cowell, BS: California Polytechnic State University, Biological Sciences Department, Bldg. 33, 1 Grand Avenue, San Luis Obispo, CA 93407.

S.N. Evetts, PhD: Captain, 23 Pioneer Regiment, St. David's Barracks, Bicester, Oxon, United Kingdom OX26 6HF.

F.B. Moore, PhD: Lockheed Martin Space Operations Corporation, NASA, Ames Research Center, Moffett Field, CA 94035-1000.

K.N. Pemberton, MA: Miltenyi Biotec, 12740 Earhart Drive, Auburn, CA 95602.

S.R. Simonson, EdD: Department of Wellness and Movement Sciences, Box 680, Western New Mexico University, Silver City, NM 88062.

J.M. Stocks, PhD: Eli Lilly Australia Pty Ltd., Asia Pacific Regional Data Management Center, Level 1, 16 Giffnock Avenue, Macquarie Park, NSW, Australia 2113.

J.M. Vener, MA: Department of Exercise and Sports Science, Room 200, University of Utah, 250 South 1850 East, Salt Lake City, UT 84112-0920.

H.W. Wilson, BS: Lockheed Martin Space Operations Corporation, NASA, Ames Research Center, Moffett Field, CA 94035-1000.

Supported by NASA: Task UPN 111-10-20; KSGC: WKU 522775-00-13; NASA EPSCoR: WKU 522635-00-04; NIH: UKGCRC MOIRR02602; GRRC MOI-RR00827

APPENDIX A1

San Francisco State University
1600 Holloway Avenue
San Francisco, California 94132

Office of Research and Sponsored Programs
415/338-2231

TO: JOHN E. GREENLEAF, PH.D.
NASA AMES RESEARCH CENTER
MOFFETT FIELD, CA 94035-1000

DATE: MAY 08, 1998

FROM: *Associate Vice President for Research and Sponsored Programs*

SUBJECT: *Protection of Human or Animal Subject Review of Research:*
EXERCISE TRAINING ON SHORT-ARM CENTRIFUGE, H.R. NO.158

The Committee for the Protection of Human Subjects (CPHS) or the University Animal Care and Use Committee (UACUC) have requested that you be advised of the current status of your planned research in terms of the protection of the rights of human or animal subjects. Please direct your attention only to the pertinent section(s) marked below. If you have any questions, please contact the Office of Research and Sponsored Programs. (338-2231.)

I. ☐ ***PENDING STATUS:***
The CPHS/UACUC is reviewing your research project with respect to the protections planned for the rights of the human or animal subjects involved. To proceed with the review, it needs, as soon as possible, the material(s) checked below:

PROTECTION OF HUMAN SUBJECTS — Materials Needed:

1. ☐ *Completion of the attached Protocol Approved Form and all necessary signatures.*
2. ☐ *An abstract of 150-200 words that describes your planned research with specific emphasis on the provisions for the protection of the rights of the human subjects involved. Be as specific as possible.*
3. ☐ *A copy of the informed Consent Form you intend to use, as appropriate, in this research effort.*
4. ☐ *Other:*____________________

PROTECTION OF ANIMAL SUBJECTS — Materials Needed:

1. ☐ *Completion of the attached Protocol Approval Form and all necessary signatures.*
2. ☐ *An abstract of 150-200 words that describes your planned research protocol with specific emphasis for the humane use of animals. Be as specific as possible.*
3. ☐ *Other:*____________________

II. ☒ ***RECORDED OR APPROVED:***

A. *Your Protocol Approval Form and supporting materials appear to be in order and have been recorded in the proceedings of the CPHS as noted below:*

1. ☐ *Exempt. Research may proceed.*

B. *The CPHS/UACUC has reviewed your research protocol and has taken the following action:*

1. ☐ *Approved, expedited review. Research may proceed.*
2. ☒ *Approved, reasonable risk. Research may proceed.*
3. ☐ *Deferred, see attached memo.*
4. ☐ *Not approved, see attached memo.*

81-196

APPENDIX A2

National Aeronautics and
Space Administration
Ames Research Center
Moffett Field, CA 94035-1000

Reply to Attn of: QH: 243-2 January 4, 1999

TO: John Greenleaf, Principal Investigator

FROM: Chair, Human Research Institutional Review Board

SUBJECT: **Certification of Approval - HR I Protocol**

Your protocol, HR # 191, "Exercise Training on the Short-arm Centrifuge", has been reviewed and approved by the Human Research Institutional Review Board. You are authorized to begin your research, subject to requirements as outlined in AMI 7170.1 (Human Research Planning and Approval). Your approval date is December 7, 1998. Approval expires on December 6, 1999.

The following conditions must be satisfied for your certification to remain in effect:

1) Modifications/changes in the project must be received and approved by the Human Research Institutional Review Board and/or by the Chairman, HRIRB before they are initiated, except when necessary, to eliminate immediate or apparent hazard to the subject.

2) The office of the Chairman, HRIRB should be notified immediately of any injuries to human subjects and/or any unanticipated problems that involve risks to human subjects or others.

3) Copies of the approved consent form(s) must be used for all investigational studies involving human subjects. In addition, all subjects must be given a copy of the consent form(s) to keep for their own records.

4) The Department of Health and Human Services and the FDA requires that the HRIRB conduct continuing review of ongoing research at intervals appropriate to the degree of risk, but not less than once per year. To meet this requirement, you must either submit a Protocol Status Report (Attachment A) by June 7, 1999 or request to address the Board during the regularly scheduled meeting preceeding this date .

5) In addition, you are also required to complete a Protocol Renewal Request Form (see Attachment B) 6 weeks prior to your protocol expiration date if you wish to conduct research beyond the certification of approval expiration date.

National Aeronautics and
Space Administration
Ames Research Center
Moffett Field, CA 94035-1000

Reply to Attn of: QH:243-2 February 16, 1999

TO: John Greenleaf, Principal Investigator

FROM: Ralph Pelligra, Chair, Human Research Institutional Review Board (HRIRB)

SUBJECT: Modification to HR I #191 entitled, "Human-Powered Centrifuge:Hormone Studies", Co-Investigator, Richard E. Grindeland

The proposed Subject modification was reviewed and approved by the HRIRB on Monday, February 8, 1999.

Ralph Pelligra, M.D.

cc: R. E. Grindeland

APPENDIX A4

National Aeronautics and
Space Administration
Ames Research Center
Moffett Field, CA 94035-1000

Reply to Attn of: QH:243-2

November 8, 1999

To: Dr. John Greenleaf, Principal Investigator

From: Ralph Pelligra, Chairman, Human Research Institutional Review Board (HRIRB)

Subject: HRI-191, "Exercise Training on the Short-Arm Centrifuge"

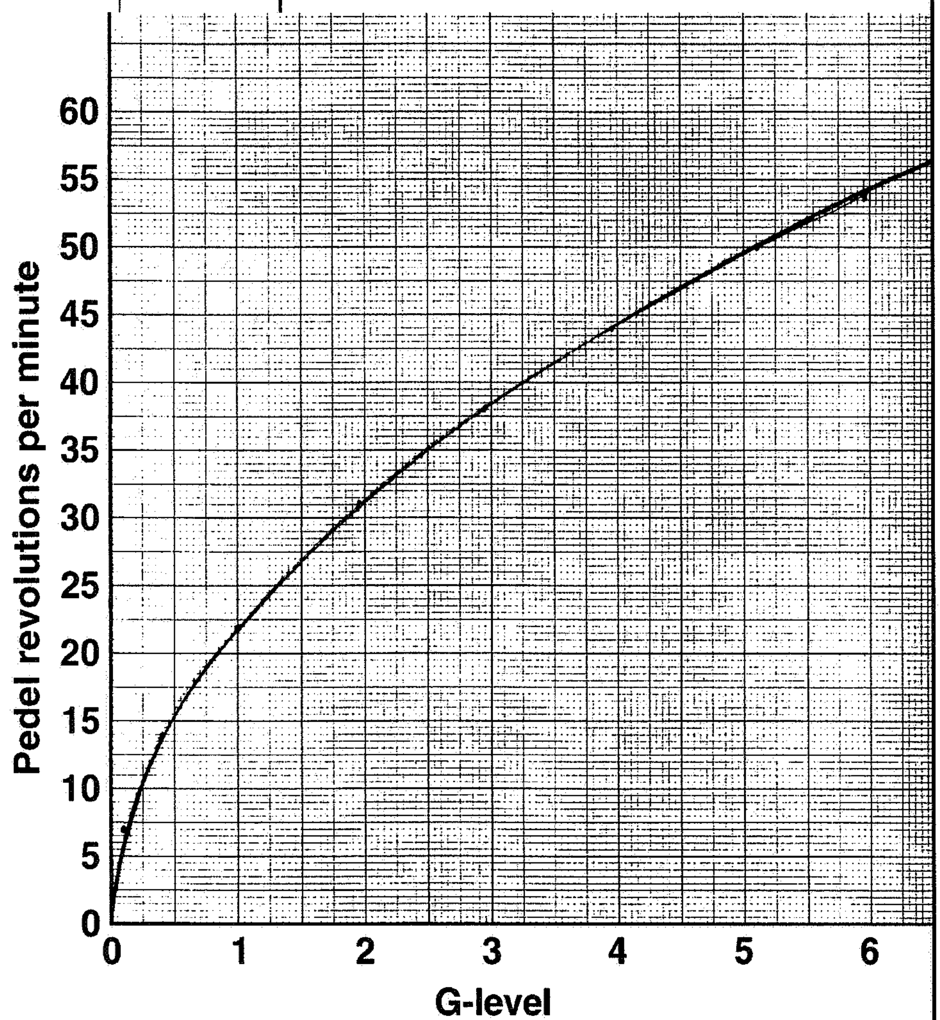
The HRIRB met on 11/1/99 and approved the following:

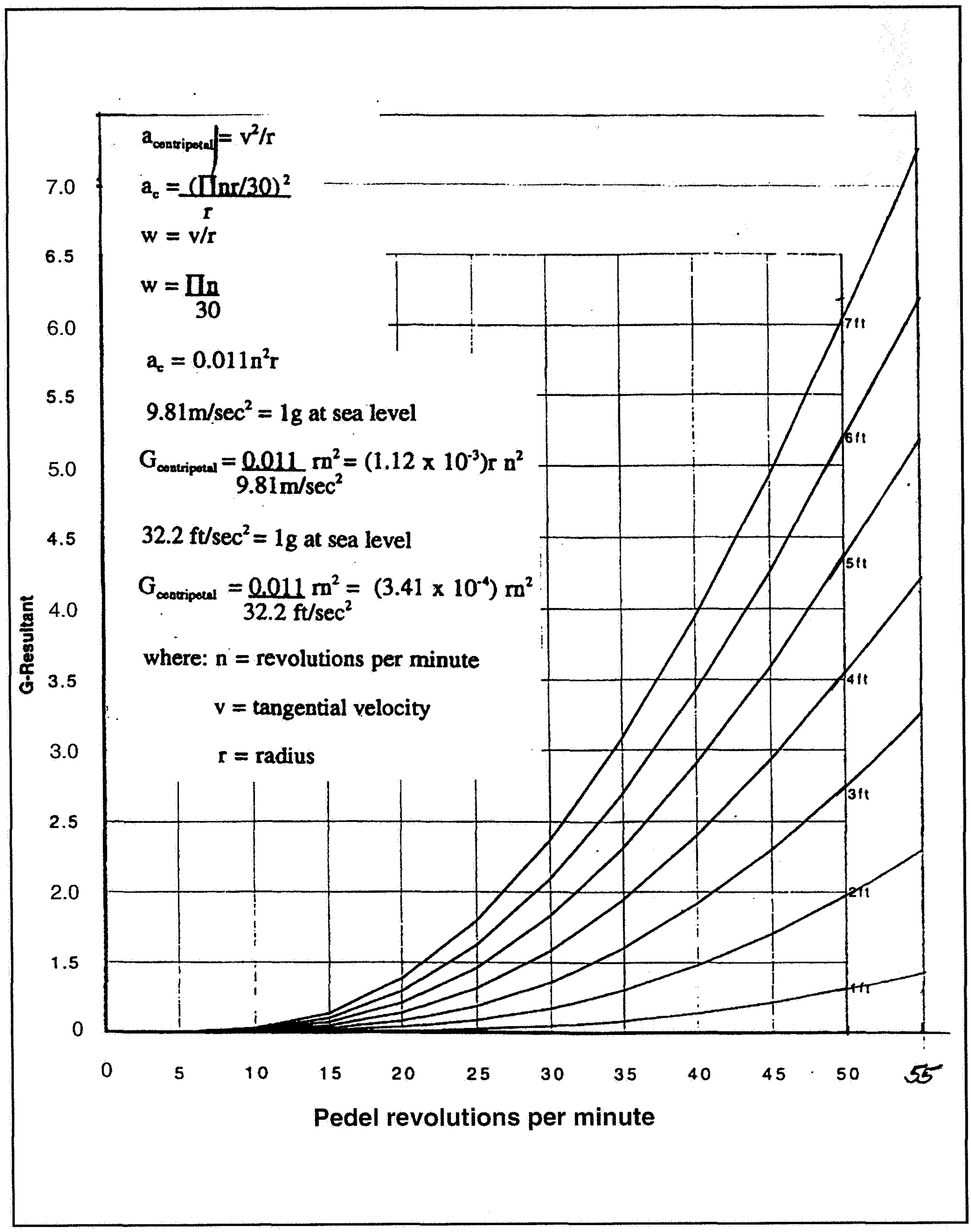
1) A one-month extension of the Subject protocol
2) The addition of two minutes of 1Gz passive warm-up; two minutes passive at 50% max; and two minutes of 1Gz passive exposure prior to HPC exercise and acceleration runs on Nov 2 and Nov 17.
3) Your responses, dated 10/14/99, to the HRIRB requests of 10/4/99.

Please contact me if you have further questions. Thank you.

Ralph Pelligra, M.D.

RPM	Gx at 6ft	RPM	Gx at 6ft
1	0.00	49	4.91
2	0.01	50	5.12
3	0.02	51	5.32
4	0.03	52	5.53
5	0.05	53	5.75
6	0.07	54	5.97
7	0.10	55	6.19
8	0.13		
9	0.17		
10	0.20		
11	0.25		
12	0.29		
13	0.34		
14	0.40		
15	0.46		
16	0.52		
17	0.59		
18	0.66		
19	0.74		
20	0.82		
21	0.90		
22	0.99		
23	1.08		
24	1.18		
25	1.28		
26	1.38		
27	1.49		
28	1.60		
29	1.72		
30	1.84		
31	1.96		
32	2.09		
33	2.22		
34	2.36		
35	2.50		
36	2.64		
37	2.79		
38	2.95		
39	3.10		
40	3.26		
41	3.43		
42	3.60		
43	3.77		
44	3.95		
45	4.13		
46	4.32		
47	4.51		
48	4.70		




$a_{centripetal} = v^2/r$
$a_c = \frac{(\Pi nr/30)^2}{r}$
$w = v/r$
$w = \frac{\Pi n}{30}$
$a_c = 0.011n^2r$
$9.81 m/sec^2 = 1g$ at sea level
$G_{centripetal} = \frac{0.011}{9.81 m/sec^2} rn^2 = (1.12 \times 10^{-3}) r\, n^2$
$32.2 ft/sec^2 = 1g$ at sea level
$G_{centripetal} = \frac{0.011}{32.2 ft/sec^2} rn^2 = (3.41 \times 10^{-4})\, rn^2$
where: n = revolutions per minute
v = tangential velocity
r = radius
G-Resultant
0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7ft
6ft
5ft
4ft
3ft
2ft
1ft
0
5
10
15
20
25
30
35
40
45
50
55
Pedel revolutions per minute

Instuments and Equipment Inventory — OXYGEN UPTAKE

equipment	model name/no.	manufacturer	manufacturer location	used for
Oxygen analyzer	CPX Express	Medical Graphics Corporation	St. Paul, MN	VO_2, HR
Laptop computer	H-1330	Quantex Microsystems, Inc.	Somerset, New Jersey	Download and store VO2 data
ECG	78202 (A, B, C)	Hewlett-Packard	Palo Alto, CA	ECG, HR during exercise
Directional Ultrasonic Flowmeter	Model 1012	LM Electronics Inc.		Doppler
Blood Pressure Monitor	Pilot	Colin Medical Instruments	San Antonio, TX	BP during exercise + acceleration
Headset	H3391	David Clark Company, Inc.	Worcester, MA	Audio contact w/subjects
Wireless beltpack	WTR-2	Clear-Com	Emeryville, CA	Audio contact w/subjects
Stopwatches		TAG Heuer	Springfield, NJ	Timing testing + training runs
Medical monitoring computer	Micron Client Pro	Micron PC, Inc.	Meridian, ID	Record ECG, Gz, BP
Biobench computer program	BioBench version 1.0 for Windows 95/NT	National Instruments Corporation	Austin, Texas	Record ECG, Gz, BP
Connector Block	SCB-100	National Instruments Corporation	Austin, Texas	Collect and channel data off of HPC platform to acquisition computer
Data acquisition card	PCI-6031E Multifunction I/O board	National Instruments Corporation	Austin, Texas	Data acquisition card in HPC computer; collect data off of HPC platform
Scale	Model 61-1320	Fairbanks Morse Weighing Systems Division, Colt Industries, Inc.		Subject height
Digital Weight Display	Model 5780	NCI	San Carlos, CA	Subject weight
Uniwork Ergometer	Model 845	Quinton	Seattle, Washington	Supine cycle testing + training
Human Powered Centrifuge	Human Powered Centrifuge	NASA Ames Research Center	Moffett Field, CA	Acceleration and exercise testing and training
Digital Tuner Metronome	DTM-12	Korg	Tokyo, Japan	Provide pedalling cadence
Printer	BJC	Canon Hi-Tech	Thailand	O_2 Data
Video Camera				Monitor subjects

APPENDIX C2

Instuments and Equipment Inventory — TILT TEST

equipment	model name/no.	manufacturer	manufacturer location	used for
Tilt table	Physical Therapy Treatment Table serial no. 499	Laberne Mfg. Co. Physical Therapy Equipment	Columbia, South Carolina	Tilting subjects
Cardiodynamic Monitor	Cardiodynamic Monitor (CDM)	BoMed Medical Mfg. Ltd. (Cardiodynamics, Inc.)	Irvine, CA	CO, SV, HR, end diastolic volume, ECG
2 Channel Skin Perfusion Meter (Laser Doppler)	PeriFlux Model PF4001	Perimed	Smithtown, NY	Skin perfusion of forearm and palm
1 Channel Skin Perfusion Meter (Laser Doppler)	LaserFlo Skin Perfusion Monitor, BPM 403A	TSI	St. Paul, MN	Skin Perfusion on head
Finapres	Ohmeda 2300 Finapres BP Monitor	Ohmeda, a division of BOC Health Care	Englewood, CO	BP
Dual Frequency Directional Doppler	Model 909	Parks Medical Electronics, Inc.	Aloha, OR	Doppler for radial artery
Plethysmograph	EC-4	D.E. Hokanson, Inc.	Issaquah, WA	Calf circumfrence
Chart recorder	MT 8800	Astro-Med, Inc.	West Warwick, RI	Tilt data acquisition
Analog Tape Recorder	TEAC Model (add 11/17/99)			
16 channel data acquisition system	Model DI-220	Dataq Instruments, Inc.	Akron, OH	Tilt data acquisition
Data acquisition computer	*Pentium II*	Comteq Computer Company	Rockville, MD	Tilt data acquisition
16 channel data acquisition card	PCI-6023E Multifunction I/O board	National Instruments Corporation	Austin, Texas	Tilt data acquisition
16 channel data acquisition BNC box	BNC 2090 and SH68-68-EP	National Instruments Corporation	Austin, Texas	Tilt data acquisition
Data acquisition software	Brown DD EX1, Biomedical Engineering	University of Kentucky	Lexington, KY	Tilt data acquisition
Sphygmomanometer	Baumanometer, Standby model	W.A. Baum Co. Inc.	Copiague, New York	Supine resting BP (pre-tilt)
Acclerometer	ADXLD EM-3	Analog Service	Roewood, MS	Tilt angle +/- 5%
Tape recorder	SR 510	TEAC	Japan	Analog record of tilt test

Instuments and Equipment Inventory — BLOOD HANDLING

equipment	model name/no.	manufacturer	manufacturer location	used for
Catheters	Quick-Cath	Baxter Healthcare Corporation	Deerfield, IL	Blood withdrawal, EB injection
Injection sites	Injection sites	Baxter Healthcare Corporation	Deerfield, IL	Blood withdrawal, EB injection
30 + 5 ml syringes	LuerLok	Becton Dickinson + Co.	Franklin Lakes, NJ	Blood withdrawal, EB injection
EB dye	25 mg in 5 ml	New World Trading Corp.	Florida	Plasma volume determination
Balance	B6 (43289)	Mettler Instrument Corp.	Highstown, NJ	Weight of Evans Blue syringes
Heparin Lock Flush Solution	Hep-Lock	Elkins-Sinn, Inc.	Cherry Hill, NJ	Hep saline
NaCl Injection	0.9% NaCl Injection, 500ml	McGaw, Inc.	Irvine, CA	Saline
Heparinized Microcapillary tubes	Red Tip	Sherwood Medical Industries	St. Louis, MO	Collecting Hct samples
Sealing cork	Seal-ease	Clay Adams	Parsippany, NJ	Sealing Hct tubes
Skin Perfusion	Periflux-2 channel	Perines	Smithtown, NY	Skin Perfusion (forearm, palm)
Microcentrifuge	Micro-MB centrifuge	International Equipment Company	Needham Heights, Mass.	Hct tube centrifugation
Micro-Capillary reader	Model CR	International Equipment Company	Needham Heights, Mass.	Hct tube reading
Blood collection tubes (EDTA + LiHep)	Vacutainer	Becton Dickinson and Company	Franklin Lakes, NJ	Initial blood collection and treatment
Refrigerated Centrifuge	RC2-B	Ivan Sorvall Inc.	Newtown, Conneticut	Blood tube centrifugation
Pipette	Pipetman	Gilson, Inc.	Middleton, Wisconson	Blood separation
Advanced Digimatic Osmometer	Model 3DII	Advanced Instruments, Inc.	Needham Heights, Mass.	Plasma osmolality
Spectrophotometer	Model 35	Beckman	Irvine, CA	Hb concentration/PV
Hemoglobin Kit	Cyanmethoemoglobin method, Kit # 525A	Sigma Diagnostics	St. Louis, MO	Hb concentration
Evans Blue	T-1824	The New World Trading Corp.	De Bary, FL	Plasma volume determination
Total protein analysis	LX2D	Beckman Coulter Synchron Analyzer	Brea, CA	
Na analysis	LX2D	Beckman Coulter Synchron Analyzer	Brea, CA	
K analysis	LX2D	Beckman Coulter Synchron Analyzer	Brea, CA	
Albumin analysis	LX2D	Beckman Coulter Synchron Analyzer	Brea, CA	
AVP analysis	See text			
Renin analysis	See text			
Catecholamines	See text			

Instuments and Equipment Inventory — **MISCELLANEOUS**

equipment	model name/no.	manufacturer	manufacturer location	used for
Data analysis	Pentium II	Comteq Computer Company	Rockville, MD	Data analysis
Data analysis	SPSS 7.5 for Windows	SPSS, Inc.	Chicago, IL	Data analysis
Data analysis	Microsoft Excel 97	Microsoft Corporation	Redmond, WA	Data analysis
Data analysis	Brown DD EX1, Biomedical Engineering	University of Kentucky	Lexington, KY	Data analysis
Refractometer	Protometer	National Instr.		Total protein and density
MRI	Vision (I-5 Tesia)	Seimans	Iselin, NJ	Leg muscles
Data acquisition and analysis		David Brown	Lexington, KY	Data analysis
Overhead camera	BL 600	Panasonic		
(2) Lip stick camera		Panasonic		
(2) Power supply	GP-KS102	Panasonic		
(2) 120V AC to 12V DC transformer	CAT No. 273-1653A	Archer		

APPENDIX D

INTENSITY OF PERCEIVED EXERTION

Name____________________ Date_____

Test_________________________

10++	Supra-maximal	
10+	Maximal	
10	Very, very strong	(almost max)
9		
8	Very strong	
7		
6		
5	Strong	(heavy)
4	Somewhat strong	
3	Moderate	
2	Weak	(light)
1	Very weak	
0.5	Very, very weak	(just noticeable)
0	Nothing at all	

VacuMed

Enter data into blue fields only

Precision O2 Calibration & Metabolic Rate Calculation

Line	Data Description	LOW RANGE	MEDIUM RANGE	HIGH RANGE
1	Enter Room Temperature (C): (10 - 39.2 Degree in 0.2 degree intervals)		22.0	
2	Enter Baro Pressure (mmHg):		770	
3	Enter Ambient Humidity (%):		43	
4	Vapor Pressure from Table*:		19.83	
5	Read True O2 Concentration:		20.71	
6	Enter CO2% of Metabolic CAL GAS:		20.99	
7	Gas Flow Liters per Minute	2.38	6.97	13.56
8	Metabolic Flow (ATPs#) in ml	500	1463	2846
9	Metabolic Flow (STPD) in ml	464	1360	2645
	Correct CPX VO2 (computed) to VO2 (simulated)			
10	Enter system's exhaled Temp Assumption (C): (10 - 39.2 in 0.2 degree intervals)		34.0	
11	Vapor Pressure from Table*:		39.90	
12	Enter system's VO2 (computed stpd):	394	1230	2380
13	Enter system's VCO2 (computed stpd):	399	1245	2550
14	Corrected VO2 (simulated STPD):	431	1344	2601
	ERROR VO2	-7.81%	-1.13%	-1.68%
15	Corrected VCO2 (simulated STPD):	436	1361	2787
	ERROR VCO2	-6.46%	0.09%	5.10%

ATPs = mixture of dry cal gas and room air is somewhat humid
* Corrected for % humidity

CPX Make & Model:

Serial No:

Date:

R/O2CAL.xls 10 Oct 1990

John Hoppe
President

4483 McGrath St. # 102 Ventura CA 93003
Tel (805) 644-7461 • (800) 235-3333
Fax (805) 654-8759 • mobile (805) 320-0654
E-mail: info@vacumed.com
Internet: www.vacumed.com

Vacumetrics Inc. / Vacu•Med Division

Serving customers around the world
in the exercise physiology and cardiopulmonary
sciences since 1968

APPENDIX F

Supine Heart Rate Max (beats • min^{-1})

Subject	PRE Training			POST Training			POST study
	passive	exercise	combined	passive	exercise	combined	
FLE			162			171	166
FRE	169	170	169	160	169	165	181
HUN	173	170	178	172	182	174	183
JAG	186	182	171	170	173	173	170
RAY	188	177	164	180	177	178	179
RUI	159	166	158	160	159	156	166
SCH	171	184		176	185		
Mean	174	175	167	170	174	170	174
SD	11	7	7	8	9	8	8
SE	4	3	3	3	4	3	3

Supine Heart Rate Max (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			6
FRE	-5	-1	-2
HUN	-1	7	-2
JAG	-9	-5	1
RAY	-4	0	9
RUI	1	-4	-1
SCH	3	1	
Mean	-3	0	2
SD	4	4	5
SE	2	2	2

Supine VO_2 Max (ml • min^{-1} • kg^{-1})

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			37.0			38.0	38.5
FRE	35.2	38.3	39.1	34.4	37.2	40.5	35.2
HUN	28.1	27.9	30.9	31.2	28.1	31.8	31.3
JAG	37.9	38.2	37.6	36.3	33.1	36.9	32.9
RAY	39.6	31.6	34.8	37.1	36.8	34.7	shut down
RUI	36.7	33.5	40.3	38.3	36.1	38.7	39.1
SCH	37.0	39.8		33.9	39.3		
Mean	35.8	34.9	36.6	35.2	35.1	36.8	35.4
SD	4.0	4.7	3.4	2.6	4.0	3.1	3.4
SE	1.6	1.9	1.4	1.0	1.6	1.3	1.4

Supine VO_2 Max (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			2.7
FRE	-2.3	-2.9	3.6
HUN	11.0	0.7	2.9
JAG	-4.2	-13.4	-1.9
RAY	-6.3	16.5	-0.3
RUI	4.4	7.8	-4.0
SCH	-8.4	-1.3	
Mean	-1.0	1.2	0.5
SD	7.3	10.1	3.0
SE	3.0	4.1	1.2

Supine Heart Rate Max (beats • min^{-1})

Subject	PRE Training			POST Training			POST study
	passive	exercise	combined	passive	exercise	combined	
FLE			162			171	166
FRE	169	170	169	160	169	165	181
HUN	173	170	178	172	182	174	183
JAG	186	182	171	170	173	173	170
RAY	188	177	164	180	177	178	179
RUI	159	166	158	160	159	156	166
SCH	171	184		176	185		
Mean	174	175	167	170	174	170	174
SD	11	7	7	8	9	8	8
SE	4	3	3	3	4	3	3

Supine Heart Rate Max (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			6
FRE	-5	-1	-2
HUN	-1	7	-2
JAG	-9	-5	1
RAY	-4	0	9
RUI	1	-4	-1
SCH	3	1	
Mean	-3	0	2
SD	4	4	5
SE	2	2	2

Supine Time to Fatigue (min)

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			725			852	810
FRE	780	815	780	750	900	865	850
HUN	840	750	715	745	900	830	840
JAG	760	807	660	810	700	840	722
RAY	725	710	640	790	710	812	800
RUI	709	700	730	750	725	795	807
SCH	780	780		855	900		
Mean	766	760	708	783	806	832	805
SD	47	49	51	44	103	26	45
SE	19	20	21	18	42	11	18

Supine Time to Fatigue (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			17.5
FRE	-3.8	10.4	10.9
HUN	-11.3	20.0	16.1
JAG	6.6	-13.3	27.3
RAY	9.0	0.0	26.9
RUI	5.8	3.6	8.9
SCH	9.6	15.4	
Mean	2.6	6.0	17.9
SD	8.4	12.0	7.8
SE	3.4	4.9	3.2

Supine Resting Heart Rate (average of tilt -5min to -2min) (beats • min^{-1})

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			52.7			53.9	
FRE	76.0	74.9	75.3	86.4	75.3	75.3	
HUN	58.3	67.2	57.2	65.6	77.2	67.5	
JAG	71.0	65.9	68.8	76.4	67.8	80.6	
RAY	50.6	46.3	55.4	49.0	45.2	47.5	
RUI	60.9	64.8	60.7	67.6	58.6	59.3	
SCH	58.2	68.5		79.1	55.4		
Mean	62.5	64.6	61.7	70.7	63.3	64.0	
SD	9.3	9.6	8.7	13.1	12.4	12.7	
SE	3.8	3.9	3.5	5.3	5.1	5.2	

Supine Resting Heart Rate (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			2.3
FRE	13.7	0.5	0.0
HUN	12.5	14.9	18.0
JAG	7.6	2.9	17.2
RAY	-3.2	-2.4	-14.3
RUI	11.0	-9.6	-2.3
SCH	35.9	-19.1	
Mean	12.9	-2.1	3.5
SD	12.8	11.5	12.3
SE	5.2	4.7	5.0

Resting Systolic BP (mmHg)

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			115.8			121.1	
FRE	131.6	130.2	137.5	154.0	129.7	129.7	
HUN	150.0	149.3	119.2	162.8	136.0	140.0	
JAG	149.8	154.7	155.6	125.1	145.8	140.1	
RAY	141.9	152.9	147.1	152.9	149.3	120.7	
RUI	162.2	146.1	151.9	163.0	144.5	153.0	
SCH	149.8	157.0		144.9	134.8		
Mean	147.6	148.4	137.9	150.5	140.0	134.1	
SD	10.2	9.7	16.9	14.2	7.6	12.6	
SE	4.2	4.0	6.9	5.8	3.1	5.2	

Resting Systolic BP (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			4.6
FRE	17.0	-0.4	-5.7
HUN	8.5	-8.9	17.4
JAG	-16.5	-5.8	-10.0
RAY	7.8	-2.4	-17.9
RUI	0.5	-1.1	0.7
SCH	-3.3	-14.1	
Mean	2.3	-5.4	-1.8
SD	11.6	5.3	12.3
SE	4.7	2.2	5.0

Resting Diastolic BP (mmHg)

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			72.5			71.8	
FRE	76.1	90.6	81.7	90.1	70.3	78.2	
HUN	88.7	76.5	65.9	102.2	82.0	79.5	
JAG	82.0	84.5	93.3	73.8	81.9	70.4	
RAY	95.6	85.2	78.8	78.6	82.5	78.3	
RUI	90.0	76.9	88.5	99.9	78.9	83.3	
SCH	81.8	88.3		70.9	80.0		
Mean	85.7	83.7	80.1	85.9	79.3	76.9	
SD	7.0	5.8	10.1	13.4	4.6	4.9	
SE	2.9	2.4	4.1	5.5	1.9	2.0	

Resting Diastolic BP (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			-1.0
FRE	18.4	-22.4	-4.3
HUN	15.2	7.2	20.6
JAG	-10.0	-3.1	-24.5
RAY	-17.8	-3.2	-0.6
RUI	11.0	2.6	-5.9
SCH	-13.3	-9.4	
Mean	0.6	-4.7	-2.6
SD	16.0	10.3	14.4
SE	6.5	4.2	5.9

Resting MAP (mmHg)

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			88.2			89.3	
FRE	91.0	104.1	98.5	106.1	87.0	94.5	
HUN	105.1	95.7	81.7	120.8	97.4	97.8	
JAG	101.6	102.6	111.5	90.1	98.6	88.5	
RAY	107.8	104.5	96.8	98.3	100.2	91.6	
RUI	110.1	94.8	107.7	119.4	97.1	102.9	
SCH	100.9	106.5		90.3	96.5		
Mean	102.8	101.4	97.4	104.2	96.1	94.1	
SD	6.8	4.9	11.3	13.7	4.7	5.5	
SE	2.8	2.0	4.6	5.6	1.9	2.3	

Resting MAP (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			1.2
FRE	16.6	-16.4	-4.1
HUN	14.9	1.8	19.7
JAG	-11.3	-3.9	-20.6
RAY	-8.8	-4.1	-5.4
RUI	8.4	2.4	-4.5
SCH	-10.5	-9.4	
Mean	1.6	-4.9	-2.3
SD	13.2	7.1	13.0
SE	5.4	2.9	5.3

Resting Pulse Pressure (mmHg)

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			43.3			49.3	
FRE	55.5	39.6	55.8	63.9	59.4	51.5	
HUN	61.3	72.8	53.3	60.6	54.0	60.5	
JAG	67.8	70.2	62.3	51.3	63.9	69.7	
RAY	46.3	67.7	68.3	74.3	66.8	42.4	
RUI	72.2	69.2	63.4	63.1	65.6	69.7	
SCH	68.0	68.7		74.0	54.8		
Mean	61.9	64.7	57.7	64.5	60.8	57.2	
SD	9.6	12.4	8.9	8.7	5.5	11.3	
SE	3.9	5.1	3.6	3.5	2.3	4.6	

Resting Pulse Pressure (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			13.9
FRE	15.1	50.0	-7.7
HUN	-1.1	-25.8	13.5
JAG	-24.3	-9.0	11.9
RAY	60.5	-1.3	-37.9
RUI	-12.6	-5.2	9.9
SCH	8.8	-20.2	
MEAN	7.7	-1.9	0.6
SD	29.5	27.1	20.5
SE	12.1	11.1	8.4

Tilt Table Tolerance Time (min)

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			60.00			60.00	60.00
FRE	60.00	60.00	60.00	60.00	60.00	60.00	60.00
HUN	60.00	60.00	59.00	60.00	60.00	35.67	58.00
JAG	22.20	45.42	25.75	28.15	26.68	17.92	28.00
RAY	31.32	45.97	15.58	60.00	60.00	41.25	60.00
RUI	29.30	60.00	60.00	60.00	60.00	60.00	60.00
SCH	58.00	49.92		60.00	34.05		
Mean	43.47	53.55	46.72	54.69	50.12	45.81	54.33
SD	17.65	7.23	20.44	13.00	15.48	17.35	12.93
SE	7.21	2.95	8.35	5.31	6.32	7.08	5.28

Tilt Table Tolerance (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			0.00
FRE	0.00	0.00	0.00
HUN	0.00	0.00	-39.54
JAG	26.80	-41.26	-30.41
RAY	91.57	30.52	164.76
RUI	104.78	0.00	0.00
SCH	3.45	-31.79	
Mean	37.77	-7.09	15.80
SD	48.03	25.86	75.02
SE	19.61	10.56	30.62

Heart Rate @ Tilt Table Tolerance Time (beats • min^{-1})

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			84			78	90
FRE	90	104	96	96	96	96	
HUN	90	108	96	96	108	90	120
JAG	66	78	108	96	120	126	108
RAY	48	66	54	66	60	72	72
RUI	48	72	72	72	60	72	72
SCH	84	102		108	90		
Mean	71	88	85	89	89	89	92
SD	20	18	20	16	25	21	21
SE	8	8	8	7	10	8	9

Heart Rate @ Tilt Table Tolerance Time (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			-7.1
FRE	6.7	-7.7	0.0
HUN	6.7	0.0	-6.3
JAG	45.5	53.8	16.7
RAY	37.5	-9.1	33.3
RUI	50.0	-16.7	0.0
SCH	28.6	-11.8	
Mean	29.1	1.4	6.1
SD	18.9	26.2	15.8
SE	7.7	10.7	6.5

MAP @ Tilt Table Tolerance (mmHg)

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			90			100	95
FRE	110	115	70	110	100	105	115
HUN	110	90	60	115	100	70	100
JAG	40	85	115	60	75	90	80
RAY	90	110	75	120	115	100	120
RUI	60	110	60	130	120	110	120
SCH	115	100		110	120		
Mean	88	102	78	108	105	96	105
SD	31	12	21	24	17	14	16
SE	13	5	9	10	7	6	7

MAP @ Tilt Table Tolerance (% change)

Subject	*% Change PRE to POST Training*		
	passive	exercise	combined
FLE			11.1
FRE	0.0	-13.0	50.0
HUN	4.5	11.1	16.7
JAG	50.0	-11.8	-21.7
RAY	33.3	4.5	33.3
RUI	116.7	9.1	83.3
SCH	-4.3	20.0	
Mean	33.4	3.3	28.8
SD	46.0	13.2	35.9
SE	18.8	5.4	14.7

R-R Interval (msec)

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	984	841	879	792	894	855	1010	929	980	850	1020	890
RAY	1190	858	1220	941	1260	932	1300	999	1100	880	1250	940
HUN	1020	696	912	662	917	619	772	560	1020	700	900	680
JAG	844	615	776	590	905	634	886	607	890	620	750	540
SCH	1020	738	761	599	889	671	1060	795				
FLE									1140	730	1120	720
FRE	776	634	701	555	813	679	788	642	790	650	810	640
Mean	972	730	875	690	946	732	969	755	987	738	975	735
SD	146	102	186	149	158	130	199	181	131	106	191	153
SE	60	42	76	61	64	53	81	74	53	43	78	62

R-R Interval (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting		
	PRE Training			POST Training					
	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	-14.53	-4.36	-13.27	-9.90	-8.02	-12.75	-10.67	12.98	4.08
RAY	-27.90	-26.03	-20.00	-22.87	-23.15	-24.80	2.52	3.17	13.64
HUN	-31.76	-32.50	-31.37	-27.41	-27.46	-24.44	-10.59	-15.81	-11.76
JAG	-27.13	-29.94	-30.34	-23.97	-31.49	-28.00	-8.06	-2.10	-15.73
SCH	-27.65	-24.52		-21.29	-25.00		-25.39	19.24	
FLE			-35.96			-35.71			-1.75
FRE	-18.30	-16.48	-17.72	-20.83	-18.53	-20.99	-9.66	-3.08	2.53
Mean	-24.55	-22.31	-24.78	-21.04	-22.28	-24.45	-10.31	2.40	-1.50
SD	6.62	10.36	9.00	5.95	8.21	7.60	8.92	12.47	10.81
SE	2.70	4.23	3.67	2.43	3.35	3.10	3.64	5.09	4.41

Stroke Volume (ml • beat-1)

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training		POST Study	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	115	71	107	71	84	59	112	80	109	75	111	73		
RAY	119	69	131	77	107	68	119	74	120	75	129	83		
HUN	135	74	117	69	120	65	92	62	147	76	108	69		
JAG	96	51	101	56	117	60	100	51	112	58	115	57		
SCH	96	55	77	52	71	44	106	63						
FLE									105	55	110	49		
FRE	59	47	65	48	68	53	67	46	64	48	65	44		
Mean	103	61	100	62	95	58	99	63	110	65	106	63		
SD	26	12	25	12	23	9	18	13	27	12	22	15		
SE	11	5	10	5	9	4	8	5	11	5	9	6		

Stroke Volume (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting		
	PRE Training			POST Training					
	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	-38	-30	-31	-34	-29	-34	-7	33	2
RAY	-42	-36	-38	-41	-38	-36	10	11	8
HUN	-45	-46	-48	-41	-33	-36	-13	-23	-27
JAG	-47	-49	-48	-45	-49	-50	5	-15	3
SCH	-43	-38		-32	-41		-20	49	
FLE			-48			-55			5
FRE	-20	-22	-25	-26	-31	-32	10	-1	2
Mean	-39	-37	-40	-37	-37	-41	-2	9	-1
SD	10	10	10	7	7	10	13	28	13
SE	4	4	4	3	3	4	5	11	5

End-Diastolic Volume (ml)

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	183	130	175	130	133	107	184	142	180	147	180	138
RAY	191	133	220	162	174	130	198	154	195	146	218	169
HUN	226	158	205	163	208	153	175	149	257	177	190.	160
JAG	170	135	174	132	203	154	180	136	194	143	190	129
SCH	152	109	119	106	120	103	168	126				
FLE									166	109	181	142
FRE	112	112	128	101	122	121	119	113	120	112	127	114
Mean	172	130	170	132	160	128	171	137	185	139	181	142
SD	38	18	40	26	40	22	27	15	45	25	30	20
SE	16	7	16	11	16	9	11	6	18	10	12	8

End-Diastolic Volume (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting		
	PRE Training			POST Training					
	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	-29	-20	-18	-26	-23	-23	-4	38	0
RAY	-30	-25	-25	-26	-22	-22	15	14	12
HUN	-30	-26	-31	-20	-15	-16	-9	-16	-26
JAG	-21	-24	-26	-24	-24	-32	2	-11	-2
SCH	-28	-14		-11	-25		-22	40	
FLE			-34			-22			9
FRE	0	-1	-7	-21	-5	-10	14	-2	6
Mean	-23	-18	-24	-21	-19	-21	-1	10	0
SD	12	10	10	6	8	7	14	24	14
SE	5	4	4	2	3	3	6	10	6

Cardiac Output ($L \bullet min^{-1}$)

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	7.04	5.15	7.38	5.46	5.75	4.19	6.77	5.25	6.75	5.29	6.54	4.96
RAY	6.05	4.90	6.53	4.95	5.15	4.42	5.55	4.48	6.60	5.16	6.23	5.39
HUN	8.06	6.47	7.85	6.43	8.18	6.44	7.22	6.75	8.85	6.66	7.27	6.23
JAG	6.87	5.11	7.97	5.82	7.81	5.42	6.85	5.00	7.61	5.67	9.26	6.32
SCH	5.69	4.55	6.13	5.30	4.85	4.03	6.05	4.76				
FLE									5.59	4.56	5.89	3.56
FRE	4.59	4.37	5.58	5.00	5.12	4.69	5.18	4.39	4.93	4.51	4.85	4.11
Mean	6.38	5.09	6.91	5.49	6.14	4.87	6.27	5.11	6.72	5.31	6.67	5.10
SD	1.21	0.74	0.97	0.56	1.47	0.91	0.81	0.87	1.40	0.80	1.50	1.12
SE	0.49	0.30	0.40	0.23	0.60	0.37	0.33	0.35	0.57	0.33	0.61	0.46

Cardiac Output (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting		
	PRE Training			POST Training					
	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	-26.85	-27.13	-21.63	-26.02	-22.45	-24.16	4.83	17.74	-3.11
RAY	-19.01	-14.17	-21.82	-24.20	-19.28	-13.48	7.93	7.77	-5.61
HUN	-19.73	-21.27	-24.75	-18.09	-6.51	-14.31	-2.61	-11.74	-17.85
JAG	-25.62	-30.60	-25.49	-26.98	-27.01	-31.75	16.01	-12.29	21.68
SCH	-20.04	-16.91		-13.54	-21.32		7.73	24.74	
FLE			-18.43			-39.56			5.37
FRE	-4.79	-8.40	-8.52	-10.39	-15.25	-15.26	21.57	1.17	-1.62
Mean	-19.34	-19.75	-20.11	-19.87	-18.64	-23.09	9.25	4.57	-0.19
SD	7.85	8.28	6.21	6.93	7.08	10.75	8.50	15.18	13.12
SE	3.20	3.38	2.54	2.83	2.89	4.39	3.47	6.20	5.36

Arterial Pressure (mmHg)

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	111	109	120	123	94	101	98	103	108	110	103	111
RAY	107	104	101	104	103	111	101	106	97	97	95	97
HUN	105	111	122	123	96	95	98	99	83	78	98	92
JAG	100	95	90	89	102	114	100	107	113	119	89	97
SCH	99	113	90	101	107	104	97	99				
FLE									90	88	88	86
FRE	90	108	107	116	105	124	88	98	100	117	95	114
Mean	102	107	105	109	101	108	97	102	99	102	95	100
SD	7	6	14	14	5	10	5	4	11	17	6	11
SE	3	3	6	6	2	4	2	2	5	7	2	4

Arterial Pressure (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting		
	PRE Training			POST Training					
	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	-2	7	2	3	5	8	8	4	-5
RAY	-3	8	0	3	5	2	-6	-2	-2
HUN	6	-1	-6	1	1	-6	16	2	18
JAG	-5	12	5	-1	7	9	-10	-2	-21
SCH	14	-3		12	2		-9	-9	
FLE			-2			-2			-2
FRE	20	18	17	8	11	20	19	-16	-5
Mean	5	7	3	4	5	5	3	-4	-3
SD	10	8	8	5	4	9	13	8	13
SE	4	3	3	2	2	4	5	3	5

Total Peripheral Resistance (mmHg/(L • min^{-1}))

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	15.77	21.17	16.26	22.53	16.31	24.11	14.42	19.62	16.04	20.87	15.82	22.46
RAY	17.69	21.22	15.47	21.01	20.00	25.11	18.20	23.66	14.67	18.76	15.20	18.00
HUN	13.03	17.16	15.54	19.13	11.67	14.77	13.55	14.65	9.36	11.64	13.47	14.83
JAG	14.48	18.63	11.29	15.34	13.06	21.03	14.53	21.40	14.81	21.01	9.57	15.33
SCH	17.45	24.84	14.60	19.06	22.06	25.81	16.03	20.80				
FLE									16.07	19.23	14.90	24.19
FRE	19.54	24.71	19.18	23.20	20.51	26.44	17.03	22.39	20.22	25.98	19.67	27.80
Mean	16.33	21.29	15.39	20.05	17.27	22.88	15.63	20.42	15.20	19.58	14.77	20.44
SD	2.37	3.11	2.55	2.86	4.26	4.40	1.77	3.14	3.50	4.66	3.29	5.21
SE	0.97	1.27	1.04	1.17	1.74	1.80	0.72	1.28	1.43	1.90	1.34	2.13

Total Peripheral Resistance (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting		
	PRE Training			POST Training					
	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	34.24	47.82	30.11	38.56	36.06	41.97	3.11	-11.59	-1.37
RAY	19.95	25.55	27.88	35.81	30.00	18.42	-12.55	-9.00	3.61
HUN	31.70	26.56	24.36	23.10	8.12	10.10	19.26	16.11	43.91
JAG	28.66	61.03	41.86	35.87	47.28	60.19	-22.03	11.26	-35.38
SCH	42.35	17.00		30.55	29.76		-16.33	-27.33	
FLE			19.66			62.35			-7.28
FRE	26.46	28.91	28.49	20.96	31.47	41.33	-1.84	-16.97	-2.72
Mean	30.56	34.48	28.73	30.81	30.45	39.06	-5.06	-6.25	0.13
SD	7.57	16.50	7.44	7.31	12.77	21.29	15.10	16.74	25.52
SE	3.09	6.74	3.04	2.98	5.21	8.69	6.16	6.84	10.42

Mean Data Summary

AP	MEAN CONT	MEAN TILT	SE CONT	SE TILT
EXB	100	107	1.79	4.43
EXA	94	100	3.16	3.43
PSB	102	107	3.05	2.61
PSA	105	109	5.77	5.53
COB	98	101	4.55	6.88
COA	95	100	2.40	4.48

RR INT	MEAN CONT	MEAN TILT	SE CONT	SE TILT
EXB	1008	758	81.02	53.53
EXA	993	749	89.39	73.55
PSB	972	730	59.74	41.78
PSA	875	690	76.04	60.74
COB	987	738	53.40	43.16
COA	975	735	77.92	62.28

SV	MEAN CONT	MEAN TILT	SE CONT	SE TILT
EXB	100	61	8.31	2.10
EXA	98	60	7.40	5.73
PSB	103	61	10.79	4.72
PSA	100	62	10.13	4.79
COB	110	64	10.94	5.09
COA	106	63	8.78	6.19

EDV	MEAN CONT	MEAN TILT	SE CONT	SE TILT
EXB	167	130	14.39	8.11
EXA	170	133	11.21	7.99
PSB	172	130	15.71	7.26
PSA	170	132	16.46	10.80
COB	186	139	18.28	10.36
COA	181	142	12.18	8.10

CO	MEAN CONT	MEAN TILT	SE CONT	SE TILT
EXB	6.17	4.93	0.59	0.35
EXA	6.11	4.96	0.39	0.41
PSB	6.38	5.09	0.49	0.30
PSA	6.91	5.49	0.40	0.23
COB	6.72	5.31	0.57	0.33
COA	6.67	5.10	0.61	0.46

TPR	MEAN CONT	MEAN TILT	SE CONT	SE TILT
EXB	16.91	22.30	1.57	1.70
EXA	15.62	20.57	0.72	1.30
PSB	16.33	21.29	0.97	1.27
PSA	15.39	20.04	1.04	1.17
COB	15.19	19.58	1.43	1.90
COA	14.77	20.43	1.34	2.13

HR	MEAN CONT	MEAN TILT	SE CONT	SE TILT
EXB	65	84	3.60	5.50
EXA	64	83	5.00	7.90
PSB	63	83	3.90	4.70
PSA	71	90	5.20	7.00
COB	62	88	3.60	7.30
COA	66	85	5.60	8.50

Hemoglobin - raw data ($g \bullet dl^{-1}$)

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training		POST Study	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	14.504	14.869	14.830	15.771	13.679	15.387	14.062	14.254	14.101	14.929	13.755	14.987	13.427	15.318
RAY	14.005	14.466	13.218	14.024	12.834	14.120	13.295	13.775	13.986	14.621	14.352	14.486	14.662	15.086
JAG	14.696	14.561	12.604	14.715	14.888	15.598	14.907	15.617	15.468	15.680	15.295	14.660	14.720	15.723
HUN	12.949	14.888	13.410	15.195	12.872	12.546	13.698	15.752	13.928	14.717	14.024	14.506	13.678	15.067
SCH	13.487	15.176	13.487	16.385	13.909	15.771	13.391	15.080						
FRE	15.598	17.018	15.579	16.942	15.195	16.596	14.293	16.078	15.545	16.161	14.929	16.527	15.067	17.189
FLE									13.466	15.276	13.331	14.198	13.948	14.913
Mean	14.206	15.163	13.854	15.505	13.896	15.003	13.941	15.093	14.416	15.231	14.281	14.894	14.250	15.549
SD	0.938	0.944	1.116	1.079	0.989	1.445	0.609	0.908	0.873	0.599	0.735	0.840	0.656	0.851
SE	0.383	0.385	0.456	0.441	0.404	0.590	0.248	0.371	0.356	0.245	0.300	0.343	0.268	0.348

Hemoglobin (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting			% Change PRE to POST Training, Tilt		
	PRE Training			POST Training								
	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	2.514	12.489	5.870	6.342	1.365	8.957	2.250	2.806	-2.457	6.067	-7.360	0.387
RAY	3.289	10.020	4.542	6.099	3.609	0.939	-5.619	3.589	2.615	-3.052	-2.447	-0.922
JAG	-0.914	4.770	1.369	16.752	4.764	-4.153	-14.236	0.129	-1.120	1.055	0.123	-6.507
HUN	14.971	-2.535	5.667	13.312	14.993	3.432	3.557	6.412	0.691	2.063	25.549	-1.439
SCH	12.524	13.386		21.490	12.614		0.000	-3.726		7.968	-4.381	
FRE	9.106	9.221	3.963	8.748	12.489	-4.900	-0.123	-5.937	-3.963	-0.451	-3.123	2.263
FLE			13.438			11.721			-1.001			-7.057
Mean	6.915	7.892	5.808	12.124	8.306	2.666	-2.362	0.546	-0.872	2.275	1.394	-2.212
SD	6.244	5.934	4.073	6.192	5.719	6.766	6.611	4.674	2.313	4.102	12.085	3.767
SE	2.549	2.423	1.663	2.528	2.335	2.762	2.699	1.908	0.944	1.675	4.934	1.538

Hemoglobin - raw data - acute exercise ($g \bullet dl^{-1}$)

Subject	PRE Combined Training		POST Combined Training	
	resting	post-exercise	resting	post-exercise
RUI	15.526	15.699	14.082	16.026
RAY	12.927	13.659	12.966	17.490
JAG	12.600	13.177	14.429	15.526
HUN	13.890	14.486	14.101	15.102
FRE			16.931	16.758
FLE	15.160	15.603	14.044	16.566
Mean	14.021	14.525	14.425	16.245
SD	1.303	1.130	1.325	0.870
SE	0.583	0.505	0.541	0.355

Hemoglobin - acute exercise (% change)

Subject	% Change Resting to Tilt	
	pre-training	post-training
RUI	1.1	13.8
RAY	5.7	34.9
JAG	4.6	7.6
HUN	4.3	7.1
FRE		-1.0
FLE	2.9	18.0
Mean	3.7	13.4
SD	1.8	12.4
SE	0.8	5.0

Hematocrit - raw data (%)

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training		POST Study	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	42.9	46.1	44.7	46.3	45.4	46.9	44.5	46.7	42.6	45.8	42.5	45.0	43.6	51.3
RAY	44.2	45.7	41.3	44.1	42.7	45.9	42.6	44.7	44.1	45.2	45.5	47.8	45.6	48.0
JAG	46.9	47.6	41.6	46.2	45.9	47.6	45.4	48.6	43.3	47.5	45.9	45.5	42.7	47.5
HUN	42.9	45.9	43.0	48.2	41.7	46.4	41.2	45.9	41.3	46.9	43.4	44.9	42.0	44.9
SCH	43.8	47.8	41.8	47.1	46.4	49.5	42.7	46.6						
FRE	47.2	50.6	45.8	49.6	44.7	51.5	43.3	48.5	46.5	48.8	46.3	49.3	44.5	49.9
FLE									41.4	47.5	42.5	46.0	42.0	47.0
Mean	44.7	47.3	43.0	46.9	44.5	48.0	43.3	46.8	43.2	47.0	44.3	46.4	43.4	48.1
SD	1.9	1.8	1.9	1.9	1.9	2.1	1.5	1.5	1.9	1.3	1.7	1.8	1.5	2.3
SE	0.8	0.8	0.8	0.8	0.8	0.9	0.6	0.6	0.8	0.5	0.7	0.7	0.6	0.9

Hematocrit (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting			% Change PRE to POST Training, Tilt		
	PRE Training			POST Training								
	passive	*exercise*	*combined*	*passive*	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	7.3	3.2	7.5	3.4	4.8	5.9	4.2	-2.0	-0.3	0.4	-0.4	-1.7
RAY	3.3	7.6	2.6	6.7	4.9	5.1	-6.6	-0.1	3.3	-3.5	-2.6	5.7
JAG	1.6	3.8	9.8	11.0	7.1	-0.8	-11.3	-1.1	6.0	-3.1	2.0	-4.3
HUN	7.0	11.3	13.6	12.2	11.4	3.3	0.2	-1.2	5.1	5.1	-1.1	-4.4
SCH	9.2	6.7		12.7	9.1		-4.5	-8.0		-1.4	-5.9	
FRE	7.0	15.3	4.9	8.3	12.0	6.5	-3.0	-3.1	-0.5	-1.8	-5.9	1.0
FLE			14.7			8.1			2.7			-3.3
Mean	5.9	8.0	8.9	9.1	8.2	4.7	-3.5	-2.6	2.7	-0.7	-2.3	-1.2
SD	2.9	4.6	4.8	3.6	3.1	3.1	5.4	2.8	2.7	3.2	3.1	3.9
SE	1.2	1.9	1.9	1.5	1.3	1.3	2.2	1.3	1.1	1.3	1.3	1.6

Hematocrit - raw data - acute exercise (%)

Subject	PRE Combined Training		POST Combined Training	
	resting	post-exercise	resting	post-exercise
RUI	44.3	49.0	43.3	46.6
RAY	44.8	46.5	45.7	46.7
JAG	46.6	47.3	43.9	45.5
HUN	43.1	44.6	43.6	44.6
FRE			48.0	49.5
FLE	46.4	49.1	43.3	47.5
Mean	45.0	47.3	44.6	46.7
SD	1.5	1.9	1.9	1.7
SE	0.7	0.8	0.8	0.7

Hematocrit - acute exercise (% change)

Subject	% Change Resting to Tilt	
	pre-training	post-training
RUI	10.6	7.6
RAY	3.8	2.2
JAG	1.5	3.5
HUN	3.3	2.4
FRE		3.1
FLE	5.8	9.7
Mean	5.0	4.8
SD	3.5	3.1
SE	1.6	1.3

Absolute Plasma Volume - raw data (ml)

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training		POST Study	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	4079.630	3805.742	3470.890	3192.531	4486.430	3905.061	4045.867	3868.697	3432.603	3097.912	4241.387	3756.186	4039.263	3157.155
RAY	3318.130	3146.151	3543.230	3212.897	3456.970	2999.932	3550.740	3326.873	3776.389	3553.297	3508.930	3360.318	3899.327	3656.194
JAG	3242.540	3236.149	3310.230	2657.322	3493.460	3249.333	3317.526	3020.003	3469.301	3218.142	3793.441	3979.466	3177.299	2772.676
HUN	3808.510	3173.732	3717.951	3040.232	3616.244	3469.462	3566.740	2902.793	4130.601	3609.798	3559.524	3371.187	3957.060	3450.962
SCH	2802.510	2348.834	3036.712	2316.454	2863.570	2410.745	3024.270	2539.537						
FRE	3295.060	2870.720	3688.616	3204.134	3780.790	3123.085	3691.250	3041.752	3443.819	3201.675	3592.624	3102.580	3823.708	3094.199
FLE									3300.000	2666.140	4024.496	3597.724	3304.174	2877.385
Mean	3424.397	3096.888	3461.272	2937.262	3616.244	3192.936	3532.732	3116.609	3592.119	3224.494	3786.734	3527.910	3700.139	3168.095
SD	452.705	477.689	255.908	370.602	527.496	498.141	344.895	447.998	307.172	342.027	293.177	314.465	364.996	336.066
SE	184.816	195.016	104.474	151.298	215.349	203.365	140.803	182.895	125.403	139.632	119.689	128.380	149.009	137.199

Plasma Volume (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting			% Change PRE to POST Training, Tilt		
	PRE Training			*POST Training*								
	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	-6.714	-12.958	-9.750	-8.020	-4.379	-11.440	-14.921	-9.820	23.562	-16.113	-0.931	21.249
RAY	-5.183	-13.221	-5.908	-9.323	-6.305	-4.235	6.784	2.712	-7.082	2.122	10.898	-5.431
JAG	-0.197	-6.988	-7.239	-19.724	-8.968	4.904	2.088	-5.036	9.343	-17.886	-7.058	23.657
HUN	-16.667	-4.059	-12.608	-18.228	-18.615	-5.291	-2.378	-1.369	-13.826	-4.206	-16.333	-6.610
SCH	-16.188	-15.813		-23.718	-16.028		8.357	5.612		-1.379	5.342	
FRE	-12.878	-17.396	-7.031	-13.135	-17.596	-13.640	11.944	-2.368	4.321	11.614	-2.604	-3.095
FLE			-19.208			-10.604			21.954			34.941
Mean	-9.638	-11.739	-10.291	-15.358	-11.982	-6.718	1.979	-1.711	6.379	-4.308	-1.781	10.785
SD	6.638	5.174	4.986	6.203	6.181	6.761	9.671	5.487	15.102	11.200	9.513	17.983
SE	2.710	2.112	2.036	2.533	2.523	2.760	3.948	2.240	6.165	4.572	3.884	7.341

Plasma Volume - raw data ($ml \bullet kg^{-1}$)

Subject	PRE Training			POST Training			POST Study
	passive	*exercise*	*combined*	*passive*	*exercise*	*combined*	
RUI	47.438	52.289	39.455	40.359	46.719	48.584	45.385
RAY	40.514	41.154	46.853	42.767	43.196	43.054	46.980
JAG	37.969	41.969	41.749	38.224	40.359	44.110	38.281
HUN	39.385		42.938	38.568	38.352	36.963	40.092
SCH	36.972	37.778	37.596	40.062	40.324	39.178	41.115
FRE	36.734	42.149		40.490	41.521		
FLE			46.479			56.051	45.891
Mean	39.835	43.068	42.512	40.078	41.745	44.657	42.957
SD	3.994	5.448	3.711	1.625	2.910	6.890	3.582
SE	1.631	2.436	1.515	0.663	1.188	2.813	1.462

Sodium - raw data (mmol • L^{-1})

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training		POST Study	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	137	135	138	137	136	136	138	136	138	137	138	136	137	136
RAY	137	136	137	137	137	136	137	136	136	136	137	137	132	135
HUN	134	135	138	137	140	135	134	135	137	136	136	135	139	135
JAG	138	135	139	137	136	137	138	137	138	136	137	136	138	137
SCH	136	135	137	137	136	134	139	137						
FLE									139	139	139	137	138	138
FRE	138	137	137	138	136	137	138	139	137	137	138	139	138	138
Mean	137	136	138	137	137	136	137	137	138	137	138	137	137	137
SD	2	1	1	0	2	1	2	1	1	1	1	1	3	1
SE	1	0	0	0	1	0	1	1	0	0	0	1	1	1

Sodium (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting			% Change PRE to POST Training, Tilt		
	PRE Training			POST Training								
	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	-1.46	0.00	-0.72	-0.72	-1.45	-1.45	0.73	1.47	0.00	1.48	0.00	-0.73
RAY	-0.73	-0.73	0.00	0.00	-0.73	0.00	0.00	0.00	0.74	0.74	0.00	0.74
HUN	0.75	-3.57	-0.73	-0.72	0.75	-0.74	2.99	-4.29	-0.73	1.48	0.00	-0.74
JAG	-2.17	0.74	-1.45	-1.44	-0.72	-0.73	0.72	1.47	-0.72	1.48	0.00	0.00
SCH	-0.74	-1.47		0.00	-1.44		0.74	2.21		1.48	2.24	
FLE			0.00			-1.44			0.00			-1.44
FRE	-0.72	0.74	0.00	0.73	0.72	0.72	-0.72	1.47	0.73	0.73	1.46	1.46
Mean	-0.85	-0.72	-0.48	-0.36	-0.48	-0.60	0.74	0.39	0.00	1.23	0.62	-0.12
SD	0.97	1.64	0.59	0.76	0.99	0.85	1.24	2.40	0.65	0.39	0.99	1.07
SE	0.40	0.67	0.24	0.31	0.41	0.35	0.51	0.98	0.27	0.16	0.40	0.44

Sodium - raw data - acute exercise (mmol • L^{-1})

Subject	PRE Combined Training		POST Combined Training	
	resting	post-exercise	resting	post-exercise
RUI	137	139	137	138
RAY	137	138	139	140
HUN	139	137	139	137
JAG	138	138	139	139
FRE			138	138
FLE	140	139	138	139
Mean	138	138	138	139
SD	1	1	1	1
SE	1	0	0	0

Sodium - acute exercise (% change)

Subject	% Change Resting to Tilt	
	Pre-training	post-training
RUI	1.46	0.73
RAY	0.73	0.72
HUN	-1.44	-1.44
JAG	0.00	0.00
FRE		0.00
FLE	-0.71	0.72
Mean	0.01	0.12
SD	1.15	0.84
SE	0.51	0.34

Potassium - raw data (mmol • L^{-1})

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training		POST Study	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	4.0	4.1	3.8	4.3	4.0	4.1	4.1	4.3	4.4	4.5	4.6	4.3	3.7	4.4
RAY	4.2	4.4	3.9	3.9	3.7	3.8	4.0	4.1	4.0	3.8	4.0	4.1	7.3	4.0
HUN	4.1	4.2	4.2	4.2	4.2	4.0	4.1	4.4	4.1	4.3	4.6	4.1	4.4	4.3
JAG	4.1	3.9	3.8	4.0	4.3	4.0	3.8	3.8	3.8	3.7	3.7	3.5	3.6	3.8
SCH	4.3	4.5	3.5	3.8	4.0	4.5	3.9	4.9						
FLE									5.4	5.6	4.3	4.7	4.0	4.5
FRE	3.9	4.0	3.7	3.7	3.8	4.1	3.4	3.8	4.1	3.9	4.1	4.0	3.7	4.0
Mean	4.1	4.2	3.8	4.0	4.0	4.1	3.9	4.2	4.3	4.3	4.2	4.1	4.5	4.2
SD	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.4	0.6	0.7	0.4	0.4	1.4	0.3
SE	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.1	0.2	0.6	0.1

Potassium (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting			% Change PRE to POST Training, Tilt		
	PRE Training			POST Training								
	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	2.5	2.5	2.3	13.2	4.9	-6.5	-5.0	2.5	4.5	4.9	4.9	-4.4
RAY	4.8	2.7	-5.0	0.0	2.5	2.5	-7.1	8.1	0.0	-11.4	7.9	7.9
HUN	2.4	-4.8	4.9	0.0	7.3	-10.9	2.4	-2.4	12.2	0.0	10.0	-4.7
JAG	-4.9	-7.0	-2.6	5.3	0.0	-5.4	-7.3	-11.6	-2.6	2.6	-5.0	-5.4
SCH	4.7	12.5		8.6	25.6		-18.6	-2.5		-15.6	8.9	
FLE			3.7			9.3			-20.4			-16.1
FRE	2.6	7.9	-4.9	0.0	11.8	-2.4	-5.1	-10.5	0.0	-7.5	-7.3	2.6
Mean	2.0	2.3	-0.3	4.5	8.7	-2.2	-6.8	-2.7	-1.0	-4.5	3.2	-3.4
SD	3.5	7.4	4.4	5.5	9.2	7.2	6.8	7.5	10.8	8.2	7.5	8.1
SE	1.4	3.0	1.8	2.3	3.8	2.9	2.8	3.1	4.4	3.3	3.1	3.3

Potassium - raw data - acute exercise (mmol • L^{-1})

Subject	PRE Combined Training		POST Combined Training	
	resting	post-exercise	resting	post-exercise
RUI	4.0	3.8	3.9	3.8
RAY	4.2	3.7	4.0	3.6
HUN	5.0	4.2	4.4	4.1
JAG	3.7	3.5	3.8	3.6
FRE			4.3	3.5
FLE	4.0	4.1	4.1	4.2
Mean	4.2	3.9	4.1	3.8
SD	0.5	0.3	0.2	0.3
SE	0.2	0.1	0.1	0.1

Potassium - acute exercise (% change)

Subject	% Change Resting to Tilt	
	pre-training	post-training
RUI	-5.000	-2.564
RAY	-11.905	-10.000
HUN	-16.000	-6.818
JAG	-5.405	-5.263
FRE		-18.605
FLE	2.500	2.439
Mean	-7.162	-6.802
SD	7.101	7.145
SE	3.176	2.917

Osmolality - raw data (mmol • L^{-1})

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training		POST Study	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	288.281	286.269	288.302	287.800	286.963	283.952	290.301	286.281	291.977	290.972	289.623	287.610	287.822	287.822
RAY	288.281	287.275	287.800	286.797	284.454	285.457	288.794	287.789	286.952	287.957	292.138	293.648	285.318	286.820
JAG	288.784	288.784	288.804	287.800	287.465	289.473	287.789	291.809	286.952	288.459	290.629	289.623	289.824	290.325
HUN	285.457	286.461	289.296	288.794	292.809	284.759	281.778	283.785	287.957	286.449	287.610	282.578	295.332	289.324
SCH	284.454	283.450	286.281	285.779	282.747	282.747	290.812	288.804						
FRE	287.967	289.473	289.296	287.789	286.460	286.962	288.804	288.804	285.946	283.936	284.591	285.597	284.317	286.820
FLE									291.977	293.987	284.591	291.635	293.329	291.326
Mean	287.204	286.952	288.297	287.460	286.816	285.558	288.046	287.879	288.627	288.627	288.197	288.449	289.324	288.739
SD	1.790	2.135	1.146	1.038	3.424	2.384	3.263	2.701	2.672	3.506	3.157	4.046	4.376	1.884
SE	0.731	0.872	0.468	0.424	1.398	0.973	1.332	1.103	1.091	1.431	1.289	1.652	1.787	0.769

Osmolality (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting			% Change PRE to POST Training, Tilt		
	PRE Training			POST Training								
	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	-0.698	-1.049	-0.344	-0.174	-1.385	-0.695	0.007	1.163	-0.806	0.535	0.820	-1.155
RAY	-0.349	0.353	0.350	-0.349	-0.348	0.517	-0.167	1.526	1.808	-0.166	0.817	1.976
JAG	0.000	0.698	0.525	-0.348	1.397	-0.346	0.007	0.113	1.282	-0.341	0.807	0.403
HUN	0.352	-2.749	-0.524	-0.174	0.712	-1.749	1.345	-3.767	-0.120	0.814	-0.342	-1.351
SCH	-0.353	0.000		-0.176	-0.690		0.642	2.852		0.822	2.142	
FRE	0.523	0.175	-0.703	-0.521	0.000	0.354	0.462	0.818	-0.474	-0.582	0.642	0.585
FLE			0.688			2.475			-2.530			-0.800
Mean	-0.088	-0.429	-0.001	-0.290	-0.052	0.092	0.383	0.451	-0.140	0.180	0.814	-0.057
SD	0.466	1.281	0.593	0.142	0.996	1.423	0.563	2.257	1.554	0.618	0.791	1.280
SE	0.190	0.523	0.242	0.058	0.407	0.581	0.230	0.921	0.635	0.252	0.323	0.523

Osmolality - raw data - acute exercise (mmol • L^{-1})

Subject	PRE Combined Training		POST Combined Training	
	resting	post-exercise	resting	post-exercise
RUI	293.333	301.334	289.306	293.823
RAY	288.333	291.333	293.321	298.340
JAG	288.333	295.333	294.325	297.336
HUN	290.333	289.333	293.321	290.310
FRE			289.808	294.325
FLE	292.833	295.833	294.325	294.325
Mean	290.633	294.633	292.016	294.826
SD	2.388	4.632	2.289	3.174
SE	1.068	2.071	0.934	1.296

Osmolality - acute exercise (% change)

Subject	% Change Resting to Tilt	
	pre-training	pre-training
RUI	2.727	1.561
RAY	1.041	1.711
JAG	2.428	1.023
HUN	-0.344	-1.027
FRE		1.559
FLE	1.025	0.000
Mean	1.375	0.805
SD	1.238	1.096
SE	0.554	0.448

Albumin - raw data ($g \bullet dl^{-1}$)

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training		POST Study	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	4.4	4.4	4.1	4.5	4.1	4.3	4.2	4.3	3.9	4.3	4.0	4.3	4.1	5.1
RAY	4.3	4.5	4.0	4.3	4.1	4.4	4.1	4.4	4.2	4.3	4.5	4.7	4.5	4.8
HUN	4.0	4.5	4.1	4.0	4.4	4.8	4.4	4.9	4.2	4.6	4.6	4.7	4.2	4.5
JAG	4.7	4.6	3.8	4.3	4.4	4.6	4.5	4.8	4.3	4.7	4.6	4.6	4.2	4.7
SCH	4.3	4.8	4.1	4.8	4.7	5.0	4.2	4.5						
FLE									4.1	5.0	4.2	4.6	4.1	4.7
FRE	4.1	4.4	4.1	4.5	3.9	4.6	3.8	4.4	4.5	4.2	4.2	4.5	3.9	4.6
Mean	4.3	4.5	4.0	4.4	4.3	4.6	4.2	4.6	4.2	4.5	4.4	4.6	4.2	4.7
SD	0.2	0.2	0.1	0.3	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.2
SE	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

Albumin (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting			% Change PRE to POST Training, Tilt		
	PRE Training			POST Training								
	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	0.0	4.9	10.3	9.8	2.4	7.5	-6.8	2.4	2.6	2.3	0.0	0.0
RAY	4.7	7.3	2.4	7.5	7.3	4.4	-7.0	0.0	7.1	-4.4	0.0	9.3
HUN	12.5	9.1	9.5	-2.4	11.4	2.2	2.5	0.0	9.5	-11.1	2.1	2.2
JAG	-2.1	4.5	9.3	13.2	6.7	0.0	-19.1	2.3	7.0	-6.5	4.3	-2.1
SCH	11.6	6.4		17.1	7.1		-4.7	-10.6		0.0	-10.0	
FLE			22.0			9.5			2.4			-8.0
FRE	7.3	17.9	-6.7	9.8	15.8	7.1	0.0	-2.6	-6.7	2.3	-4.3	7.1
Mean	5.7	8.4	7.8	9.1	8.4	5.1	-5.8	-1.4	3.7	-2.9	-1.3	1.4
SD	6.0	5.0	9.5	6.6	4.6	3.6	7.5	4.9	5.8	5.4	5.1	6.3
SE	2.4	2.0	3.9	2.7	1.9	1.5	3.1	2.0	2.4	2.2	2.1	2.6

Albumin - raw data - acute exercise ($g \bullet dl^{-1}$)

Subject	PRE Combined Training		POST Combined Training	
	resting	post-exercise	resting	post-exercise
RUI	4.1	4.8	4.1	4.5
RAY	4.2	4.5	4.3	4.4
HUN	4.3	4.5	4.4	4.4
JAG	4.4	4.6	4.2	4.4
FRE			4.3	4.4
FLE	4.6	4.9	4.2	4.7
Mean	4.3	4.7	4.3	4.5
SD	0.2	0.2	0.1	0.1
SE	0.1	0.1	0.0	0.0

Albumin - acute exercise (% change)

Subject	% Change Resting to Tilt	
	pre-training	post-training
RUI	17.07	9.76
RAY	7.14	2.33
HUN	4.65	0.00
JAG	4.55	4.76
FRE		2.33
FLE	6.52	11.90
Mean	7.99	5.18
SD	5.21	4.68
SE	2.33	1.91

Total Protein - raw data ($g \bullet dl^{-1}$)

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training		POST Study	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	7.0	6.8	6.9	7.4	6.6	6.7	7.0	7.3	6.8	7.3	6.7	7.3	6.7	8.5
RAY	7.3	7.6	6.9	7.6	7.0	7.8	7.0	7.5	7.4	7.6	7.9	8.2	7.8	8.4
HUN	6.9	7.7	6.9	8.3	6.8	7.6	7.3	8.3	7.2	7.7	7.4	7.8	6.4	7.6
JAG	7.5	7.6	6.4	7.2	7.3	7.6	7.4	8.0	7.0	7.7	7.5	7.5	6.9	7.7
SCH	7.0	7.7	6.7	7.6	7.8	7.9	6.9	7.4						
FLE									6.1	7.5	6.2	7.0	6.8	7.2
FRE	6.5	7.1	6.5	7.1	6.0	7.0	6.1	7.0	7.1	6.7	6.6	7.3	5.8	7.0
Mean	7.0	7.4	6.7	7.5	6.9	7.4	7.0	7.6	6.9	7.4	7.1	7.5	6.7	7.7
SD	0.3	0.4	0.2	0.4	0.6	0.5	0.5	0.5	0.5	0.4	0.6	0.4	0.7	0.6
SE	0.1	0.2	0.1	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.3	0.2

Total Protein (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting			% Change PRE to POST Training, Tilt		
	PRE Training			POST Training								
	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	-2.9	1.5	7.4	7.2	4.3	9.0	-1.4	6.1	-1.5	8.8	9.0	0.0
RAY	4.1	11.4	2.7	10.1	7.1	3.8	-5.5	0.0	6.8	0.0	-3.8	7.9
HUN	11.6	11.8	6.9	20.3	13.7	5.4	0.0	7.4	2.8	7.8	9.2	1.3
JAG	1.3	4.1	10.0	12.5	8.1	0.0	-14.7	1.4	7.1	-5.3	5.3	-2.6
SCH	10.0	1.3		13.4	7.2		-4.3	-11.5		-1.3	-6.3	
FLE			23.0			12.9			1.6			-6.7
FRE	9.2	16.7	-5.6	9.2	14.8	10.6	0.0	1.7	-7.0	0.0	0.0	9.0
Mean	5.6	7.8	7.4	12.1	9.2	6.9	-4.3	0.8	1.6	1.7	2.2	1.5
SD	5.7	6.4	9.4	4.6	4.1	4.8	5.6	6.7	5.3	5.5	6.6	6.0
SE	2.3	2.6	3.8	1.9	1.7	1.9	2.3	2.7	2.2	2.2	2.7	2.5

Total Protein - raw data - acute exercise (g • dl^{-1})

Subject	PRE Combined Training		POST Combined Training	
	resting	post-exercise	resting	post-exercise
RUI	7.0	8.0	6.8	7.4
RAY	7.6	8.0	7.6	7.8
HUN	7.1	7.5	7.2	7.6
JAG	7.2	7.6	6.9	7.3
FRE			6.9	7.1
FLE	6.7	7.2	6.3	7.2
Mean	7.1	7.7	7.0	7.4
SD	0.3	0.3	0.4	0.3
SE	0.1	0.2	0.2	0.1

Total Protein - *acute exercise (% change)*

Subject	% Change Resting to Tilt	
	pre-training	post-training
RUI	14.29	8.82
RAY	5.26	2.63
HUN	5.63	5.56
JAG	5.56	5.80
FRE		2.90
FLE	7.46	14.29
Mean	7.64	6.67
SD	3.81	4.36
SE	1.71	1.78

PRA - raw data (ngAng1 • ml^{-1} • hr^{-1})

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training		POST Study	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	0.493	1.215	0.406	0.821	0.485	0.939	0.435	0.844	0.497	1.390	0.527	1.114		
RAY	0.596	1.32	0.164	1.342	0.186	1.344	0.208	1.425	0.338	0.861	0.201	0.767		
HUN	0.602	1.646	0.63	1.912	0.468	1.14	0.737	2.277	0.550	1.500	0.638	1.583	0.464	1.338
JAG	0.667	2.471	0.435	1.292	0.42	2.07	0.692	2.633	2.135	1.390	0.338	1.114	0.419	2.135
SCH	1.39	5.633	0.894	4.338	0.781	4.539	0.578	2.052						
FLE									0.352	1.425	0.648	1.994		2.015
FRE	0.86	2.552	0.91	2.912	0.363	1.709	0.717	2.094	0.612	2.497	0.819	2.927		1.968
Mean	0.768	2.473	0.573	2.103	0.451	1.957	0.561	1.888	0.747	1.511	0.529	1.583	0.442	1.864
SD	0.328	1.648	0.295	1.309	0.195	1.328	0.207	0.645	0.688	0.535	0.225	0.785	0.032	0.358
SE	0.134	0.673	0.120	0.534	0.079	0.542	0.084	0.263	0.281	0.218	0.092	0.320	0.023	0.179

PRA (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting			% Change PRE to POST Training, Tilt		
	PRE Training			POST Training								
	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	146.450	93.608	179.678	102.217	94.023	111.385	-17.647	-10.309	6.036	-32.428	-10.117	-19.856
RAY	121.477	622.581	154.734	718.293	585.096	281.592	-72.483	11.828	-40.533	1.667	6.027	-10.918
HUN	173.422	143.590	172.727	203.492	208.955	148.119	4.651	57.479	16.000	16.160	99.737	5.533
JAG	270.465	392.857	-34.895	197.011	280.491	229.586	-34.783	64.762	-84.169	-47.713	27.198	-19.856
SCH	305.252	481.178		385.235	255.017		-35.683	-25.992		-22.990	-54.792	
FLE			304.830			207.716			84.091			39.930
FRE	196.744	370.799	308.007	220.000	192.050	257.387	5.814	97.521	33.824	14.107	22.528	17.221
Mean	202.302	350.769	180.847	304.375	269.272	205.964	-25.022	32.548	2.542	-11.866	15.097	2.009
SD	71.780	201.055	125.567	222.512	167.563	65.140	29.486	48.112	58.645	26.362	50.927	23.686
SE	29.304	82.080	51.262	90.840	68.407	26.593	12.038	19.642	23.942	10.762	20.791	9.670

Aldosterone - raw data ($pg \cdot ml^{-1}$)

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	149.087	357.806	102.642	250.962	125.598	177.032	70.365	278.832
RAY	74.245	201.832	60.847	222.110	83.356	279.259	88.277	397.239
HUN	111.086	237.211	64.978	351.807	14.914	147.741	104.705	299.916
JAG	148.937	197.230	61.102	198.811	128.596	293.518	115.886	154.855
SCH	142.308	332.195	55.110	187.267	103.822	217.047	69.904	137.984
FLE								
FRE	64.680	331.408	89.960	392.905	22.154	310.478	33.381	323.423
Mean	115.057	276.280	72.440	267.310	79.740	237.513	80.420	265.375
SD	38.125	72.291	19.173	85.233	50.202	66.842	29.440	100.573
SE	15.565	29.513	7.827	34.796	20.495	27.288	12.019	41.059

Aldosterone (% change)

Subject	% Change Resting to Tilt				% Change PRE to POST Training, Resting		% Change PRE to POST Training, Tilt	
	PRE Training		POST Training					
	passive	exercise	passive	exercise	passive	exercise	passive	exercise
RUI	139.998	40.951	144.502	296.265	-31.153	-43.976	-29.861	57.504
RAY	171.846	235.020	265.030	349.992	-18.046	5.904	10.047	42.248
HUN	113.538	890.620	441.425	186.439	-41.507	602.058	48.310	103.001
JAG	32.425	128.248	225.376	33.627	-58.975	-9.884	0.802	-47.242
SCH	133.434	109.057	239.806	97.391	-61.274	-32.669	-43.627	-36.427
FLE								
FRE	412.381	1301.453	336.755	868.883	39.085	50.677	18.556	4.169
Mean	167.270	450.891	275.482	305.433	-28.645	95.352	0.704	20.542
SD	128.887	520.080	102.313	300.288	37.029	250.449	33.382	57.870
SE	52.618	212.322	41.769	122.592	15.117	102.246	13.628	23.626

AVP - raw data (pg • ml^{-1})

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training		POST Study	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	0.430	148.935	0.300	1.380	1.855	3.612	0.836	0.602	12.410	6.700	8.110	7.560		
RAY	0.820	43.913	2.798	4.434	1.092	10.451	1.956	2.035	6.180	64.050	2.320	4.830		
HUN	3.500	5.928	2.035	5.316	3.500	7.477	2.213	5.435	2.530	8.460	3.070	5.970	1.290	5.160
JAG	0.955	230.047	0.300	188.264	0.300	184.579	2.709	154.067	5.580	5.780	2.460	10.080	0.300	116.490
SCH	3.388	4.050	1.371	2.297	0.300	1.577	2.346	1.952						
FLE									7.010	3.470	2.080	2.200		10.480
FRE	1.248	3.353	3.458	3.210	1.641	2.341	3.073	4.528	6.742	5.630	5.810	5.180		6.220
Mean	1.724	72.704	1.710	34.150	1.448	35.006	2.189	28.103	6.742	15.682	3.975	5.970	0.795	34.588
SD	1.359	95.267	1.299	75.513	1.198	73.353	0.770	61.735	3.213	23.751	2.446	2.667	0.700	54.650
SE	0.555	38.893	0.530	30.828	0.489	29.946	0.314	25.203	1.312	9.696	0.998	1.089	0.495	27.325

AVP (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting			% Change PRE to POST Training, Tilt		
	PRE Training			POST Training								
	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	34536.047	94.717	-46.011	360.000	-27.990	-6.782	-30.233	-54.933	-34.649	-99.073	-83.333	12.836
RAY	5255.244	857.051	936.408	58.470	4.039	108.190	241.220	79.121	-62.460	-89.903	-80.528	-92.459
HUN	69.371	113.629	234.387	161.229	145.594	94.463	[illegible]	-36.771	21.344	-10.324	-27.310	-29.433
JAG	23988.691	61426.333	3.584	62654.667	5587.228	309.756	[illegible]	803.000	-55.914	-18.163	-16.531	74.394
SCH	19.540	425.667		67.542	-16.795		-59.534	682.000		-43.284	23.779	
FLE			-50.499			5.769			-70.328			-36.599
FRE	168.670	42.657	-16.494	-7.172	47.348	-10.843	177.083	87.264	-13.824	-4.265	93.422	-7.993
Mean	10672.927	10493.342	176.896	10549.123	956.571	83.425	36.349	259.947	-35.972	-44.169	-15.084	-13.209
SD	14915.621	24953.847	387.039	25526.719	2269.426	122.487	136.038	380.196	34.805	41.282	66.897	55.625
SE	6089.277	10187.365	158.008	10421.239	926.489	50.005	55.537	155.214	14.209	16.853	27.311	22.709

Epinephrine - raw data (pg • ml^{-1})

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training		POST Study	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	28.029	144.016	20.248	34.242	16.376	30.616	36.512	15.312	15.563	25.002	21.920	22.313	18.430	22.880
RAY	17.545	40.960	14.917	30.132	18.444	65.170	27.253	34.269	17.131	84.813	17.092	23.246	14.471	13.906
HUN	18.048	59.483	38.082	63.720	36.772	96.789	40.816	86.018	25.210	83.093	58.276	51.451	20.651	75.989
JAG	41.816	334.930	38.237	138.135	36.268	124.241	27.369	163.797	33.476	34.893	30.851	46.949	20.543	*missing*
SCH	13.125	33.273	20.450	16.515	47.070	52.434	18.654	46.616					.	
FRE	30.916	23.385	24.923	24.689	26.457	33.069	25.007	37.487	35.293	22.777	28.727	18.352	20.878	20.970
FLE									48.126	29.167	30.435	22.222	10.080	44.092
Mean	24.913	106.008	26.143	51.239	30.231	67.053	29.269	63.917	29.133	46.624	31.217	30.756	17.509	35.567
SD	10.694	120.302	9.833	45.501	11.899	37.026	8.054	54.229	12.338	29.213	14.318	14.456	4.375	25.248
SE	4.366	49.113	4.014	18.576	4.858	15.116	3.288	22.139	5.037	11.926	5.845	5.902	1.786	11.291

Epinephrine (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting			% Change PRE to POST Training, Tilt		
	PRE Training			POST Training								
	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	413.811	86.957	60.650	69.113	-58.063	1.793	-27.761	122.960	40.847	-76.223	-49.987	-10.755
RAY	133.457	253.340	395.085	101.998	25.744	36.005	-14.979	47.761	-0.228	-26.436	-47.416	-72.591
HUN	229.582	163.214	229.603	67.323	110.746	-11.712	111.004	10.997	131.162	7.123	-11.128	-38.080
JAG	700.961	242.564	4.233	261.260	498.476	52.180	-8.559	-24.537	-7.841	-58.757	31.838	34.551
SCH	153.509	11.396		-19.242	149.898		55.810	-60.370		-50.365	-11.096	
FRE	-24.360	24.991	-35.463	-0.939	49.906	-36.116	-19.385	-5.481	-18.604	5.576	13.360	-19.427
FLE			-39.395			-26.985			-36.760			-23.811
Mean	267.827	130.410	102.452	79.919	129.451	2.528	16.022	15.222	18.096	-33.180	-12.405	-21.686
SD	255.686	105.766	174.549	100.018	194.521	35.082	55.390	63.887	61.100	34.566	32.443	35.077
SE	104.383	43.179	71.259	40.832	79.413	14.322	22.613	26.082	24.944	14.112	13.245	14.320

Epinephrine - raw data - acute exercise ($pg \bullet ml^{-1}$)

Subject	PRE Combined Training		POST Combined Training	
	resting	post-exercise	resting	post-exercise
RUI	54.082	*missing*	*missing*	54.266
RAY	31.500	64.149	18.761	66.705
HUN	29.036	48.546	58.940	43.083
JAG	43.424	56.128	23.978	55.807
FRE			19.834	102.327
FLE	22.554	69.892	23.978	67.166
Mean	36.119	59.679	29.098	64.892
SD	12.565	9.325	16.850	20.401
SE	5.619	4.662	7.535	8.329

Epinephrine - acute exercise (% change)

Subject	% Change Resting to Tilt	
	pre-training	post-training
RUI		
RAY	103.648	255.551
HUN	67.192	-26.904
JAG	29.256	132.743
FRE		415.917
FLE	209.887	180.115
Mean	102.496	191.485
SD	77.770	162.594
SE	38.885	72.714

Norepinephrine - raw data ($pg \bullet ml^{-1}$)

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training		POST Study	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	169.172	212.949	175.499	314.789	162.432	257.912	215.705	245.747	223.676	399.289	171.708	267.670	189.042	375.817
RAY	276.897	326.257	208.384	362.776	453.670	544.551	372.298	473.356	267.709	446.010	320.078	385.135	439.785	375.905
HUN	173.142	489.283	145.396	525.802	170.992	470.814	264.716	767.811	166.873	407.244	190.477	387.404	194.068	551.196
JAG	323.645	671.999	185.571	395.282	192.055	391.816	211.841	617.460	140.300	335.193	192.742	221.498	144.963	*missing*
SCH	326.938	614.880	273.698	575.111	263.230	657.913	244.534	663.757						
FRE	194.895	503.182	206.904	531.035	179.355	563.161	241.860	718.770	277.457	385.217	288.196	664.631	241.349	414.663
FLE									178.433	314.192	143.585	390.813	151.927	381.555
Mean	244.115	469.758	199.242	450.799	236.956	481.028	258.492	581.150	209.075	381.191	217.798	386.192	226.856	419.827
SD	73.940	173.207	43.211	106.626	112.156	141.360	59.108	192.893	56.173	48.639	69.890	154.093	109.886	75.192
SE	30.186	70.712	17.641	43.530	45.787	57.710	24.131	78.748	22.933	19.857	28.533	62.908	44.861	33.627

Norepinephrine (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting			% Change PRE to POST Training, Tilt		
	PRE Training			POST Training								
	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	25.877	58.782	78.512	79.368	13.927	55.887	3.740	32.797	-23.234	47.824	-4.717	-32.963
RAY	17.826	20.032	66.603	74.090	27.144	20.325	-24.743	-17.936	19.562	11.193	-13.074	-13.649
HUN	182.591	175.343	144.044	261.634	190.051	103.386	-16.025	54.812	14.145	7.464	63.082	-4.872
JAG	107.635	104.012	138.912	113.008	191.473	14.919	-42.662	10.302	37.378	-41.178	57.589	-33.919
SCH	88.072	149.938		110.126	171.438		-16.284	-7.103		-6.468	0.888	
FRE	158.181	213.992	38.838	156.658	197.184	130.618	6.162	34.850	3.871	5.535	27.631	72.534
FLE			76.084			172.182			-19.530			24.387
Mean	96.697	120.350	90.499	132.481	131.870	82.886	-14.969	17.954	5.365	4.062	21.900	1.920
SD	67.213	73.198	41.958	69.821	86.772	63.142	18.231	27.708	23.424	28.765	32.789	40.696
SE	27.440	29.883	17.129	28.504	35.425	25.778	7.443	11.312	9.563	11.743	13.386	16.614

Norepinephrine - raw data - acute exercise (pg • ml^{-1})

Subject	PRE Combined Training		POST Combined Training	
	resting	post-exercise	resting	post-exercise
RUI	237.392	*missing*	*missing*	235.102
RAY	266.089	781.450	457.296	1079.190
HUN	173.154	437.889	240.208	556.476
JAG	139.143	663.536	110.318	400.582
FRE			354.625	1292.650
FLE	208.973	735.650	181.977	467.804
Mean	204.950	654.631	268.885	671.967
SD	50.369	152.429	138.175	417.277
SE	22.526	76.214	61.794	170.353

Norepinephrine - acute exercise (% change)

Subject	% Change Resting to Tilt	
	pre-training	post-training
RUI		
RAY	193.680	135.994
HUN	152.890	131.664
JAG	376.873	263.116
FRE		264.512
FLE	252.031	157.068
Mean	243.869	190.471
SD	97.558	67.641
SE	48.779	30.250

Dopamine - raw data ($pg \cdot ml^{-1}$)

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training		POST Study	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	4.193	9.119	10.500	11.567	18.684	8.971	13.661	0.497	7.488	8.899	29.818	22.133	4.881	15.548
RAY	18.871	16.748	10.219	7.704	10.475	8.514	9.033	7.042	4.111	6.655	13.452	8.164	3.380	3.764
HUN	17.376	50.139	202.880	14.158	1.611	14.401	20.237	35.581	3.501	12.495	10.893	9.545	8.397	13.340
JAG	24.251	23.293	24.206	9.646	12.452	33.404	24.811	16.466	2.411	5.992	9.144	10.001	1.736	missing
SCH	38.563	24.781	25.591	12.282	32.459	32.878	8.341	20.785						
FRE	14.231	22.141	7.004	16.473	11.954	31.145	192.340	17.557	10.530	-4.145	4.653	11.189	15.204	10.004
FLE									24.049	8.685	12.671	6.030	2.886	11.001
Mean	19.581	24.370	46.733	11.972	14.606	21.552	44.737	16.321	8.682	6.430	13.439	11.177	6.081	10.731
SD	11.427	13.864	76.891	3.128	10.324	12.167	72.594	12.074	8.100	5.658	8.614	5.651	5.028	4.448
SE	4.665	5.660	31.390	1.277	4.215	4.967	29.636	4.929	3.307	2.310	3.517	2.307	2.053	1.989

Dopamine (% change)

Subject	% Change Resting to Tilt						% Change PRE to POST Training, Resting			% Change PRE to POST Training, Tilt		
	PRE Training			POST Training								
	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined	passive	exercise	combined
RUI	117.482	-51.986	18.843	10.162	-96.362	-25.773	150.417	-26.884	298.210	26.845	-94.460	148.713
RAY	-11.250	-18.721	61.883	-24.611	-22.041	-39.310	-45.848	-13.766	227.220	-54.000	-17.289	22.675
HUN	188.553	793.917	256.898	-93.021	75.822	-12.375	1067.587	1156.176	211.140	-71.763	147.073	-23.609
JAG	-3.950	168.262	148.528	-60.150	-33.634	9.372	-0.186	99.253	279.262	-58.588	-50.707	66.906
SCH	-35.739	1.291		-52.007	149.191		-33.638	-74.303		-50.438	-36.781	
FRE	55.583	160.540	-139.364	135.194	-90.872	140.469	-50.784	1509.001	-55.812	-25.600	-43.628	-369.940
FLE			-63.886			-52.411			-47.312			-30.570
Mean	51.780	175.551	47.150	-14.072	-2.983	3.329	181.258	441.580	152.118	-38.924	-15.965	-30.971
SD	86.921	317.029	143.113	80.962	97.071	70.516	440.693	701.450	161.021	35.575	83.845	178.717
SE	35.485	129.426	58.426	33.052	39.629	28.788	179.912	286.366	65.737	14.524	34.230	72.961

Dopamine - raw data - acute exercise (pg • ml^{-1})

Subject	PRE Combined Training		POST Combined Training	
	resting	post-exercise	resting	post-exercise
RUI	3.779	*missing*	*missing*	52.459
RAY	8.098	28.476	11.667	27.252
HUN	4.037	9.704	32.832	15.210
JAG	6.271	22.096	-1.084	11.547
FRE			9.247	53.940
FLE	4.602	25.677	8.913	20.596
Mean	5.357	21.488	12.315	30.167
SD	1.813	8.279	12.469	18.615
SE	0.811	4.139	5.576	7.600

Dopamine - acute exercise (% change)

Subject	% Change Resting to Tilt	
	pre-training	post-training
RUI		
RAY	251.642	133.582
HUN	140.377	-53.673
JAG	252.352	-1165.221
FRE		483.324
FLE	457.953	131.078
Mean	275.581	-94.182
SD	132.480	629.464
SE	66.240	281.505

Plasma Human Growth Hormone (ng • ml^{-1})

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training		POST Study	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
RUI	1	1 #	1	1	1	1	1	1	1	1	1	1	1	1
RAY	1	16.0 #	1	17.1	1	7.7 #	1	6.4	1	6.8 #	1	7.4 #	1	9.3
JAG	1	22.4 #	1	3.7 #	6.2	4.7 #	1	16.0 #	6.6	7.1 #	1	1 #	1	1.6
HUN	1	18.5	1	3.0	1	6.0	1	7.1	1	2.9 #	1	1.5 #	1	2.4
SCH	1	1 #	1	1	1	2.0 #	1	1 #						
FRE	1	1	1	1	1	1	1	1	1	1	1	1	1	1
FLE									1	1	1	1	1	1
Mean	1	10.0	1	4.5	1.9	3.7	1	5.4	1.9	3.3	1	2.2	1	2.7
SD	0	10.0	0	6.3	2.1	2.8	0	5.9	2.3	2.9	0	2.6	0	3.3
SE	0	4.1	0	2.6	0.9	1.2	0	2.4	0.9	1.2	0	1.1	0	1.3

Individual radioimmunoassay data. # Pre-syncopal signs or symptoms.

Plasma Human Growth Hormone (ng HGH • ml^{-1})

Subject	PRE Passive Training		POST Passive Training		PRE Exercise Training		POST Exercise Training		PRE Combined Training		POST Combined Training	
	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt	resting	post-tilt
Mean	725	2125	775	575	720	775	730	1850	1375	2075	1205	2000
SE	84	99	85	81	84	85	84	97	93	99	91	98
CL	693-763	1858-2428	660-910	498-703	643-818	730-823	643-838	1688-2033	1180-1595	1820-2388	1105-1315	1893-2103
	P < 0.001		NS		NS		P < 0.001		P < 0.001		P < 0.001	

Mean summed bioassy data. CL = 95% confidence limits. NS = not significant.

Plasma Human Growth Hormone (ng • ml^{-1})

Subject	BEFORE Combined Training		AFTER Combined Training	
	pre exercise	post exercise	pre exercise	post exercise
RUI	1	1	1	1
RAY	1	10.9	1	1.5
JAG	1	6.2	1	13.5
HUN	1	1	1	1
SCH				
FRE			1	26.6
FLE	1	1	1	1
Mean	1	4.0	1	7.4
SD	0	4.5	0	10.6
SE	0	2.0	0	4.3

Individual radioimmunoassay data.

Urine Volume (ml)

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			2295			1935	1085
FRE	3945	3065	2975	3000	3350	3395	3355
HUN	2730	2990	1435	2390	2020	2645	2015
JAG	3162	1640	1365	2570	1710	1485	2065
RAY	710	965	1025	1030	780	1045	926
RUI	1760	1805	1575	1270	1760	2185	1815
SCH	750	1082		810	1140		
Mean	2176	1925	1778	1845	1793	2115	1877
SD	1324	912	721	919	887	836	869
SE	540	372	294	375	362	341	355
ml / min^{-1}	1.5	1.3	1.2	1.3	1.2	1.5	1.3

Urine Volume (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			-16
FRE	-24	9	14
HUN	-12	-32	84
JAG	-19	4	9
RAY	45	-19	2
RUI	-28	-2	39
SCH	8	5	
Mean	-5	-6	22
SD	28	16	35
SE	11	7	14

Creatinine (mg • 24 hr^{-1})

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			6265			2187	1172
FRE	986	1624	1190	1080	1173	985	772
HUN	956	2063	1521	1745	1252	2566	3949
JAG	3826	2214	1119	1491	770	3104	2003
RAY	2109	1891	2081	2410	1724	2174	1889
RUI	1549	2274	2741	2337	2534	1901	1289
SCH	705	822		1361	1516		
Mean	1689	1815	2486	1737	1495	2153	1846
SD	1163	540	1949	538	603	708	1128
SE	475	221	796	220	246	289	461

Creatinine (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			-65.1
FRE	9.5	-27.8	-17.2
HUN	82.5	-39.3	68.7
JAG	-61.0	-65.2	177.4
RAY	14.3	-8.8	4.5
RUI	50.9	11.4	-30.6
SCH	93.0	84.4	
Mean	31.5	-7.5	22.9
SD	56.8	52.1	87.8
SE	23.2	21.3	35.8

Deoxypyridinoline (DPD) (nmol • L^{-1})

Subject	PRE Training			POST Training			POST Study
	passive	*exercise*	*combined*	*passive*	*exercise*	combined	
FLE			112.8			40.9	37.3
FRE	13.0	8.4	9.2	12.3	7.3	10.1	9.6
HUN	17.0	25.2	53.4	27.5	32.3	50.2	127.8
JAG	28.3	33.9	30.5	15.5	14.3	60.1	26.3
RAY	63.1	49.3	38.3	66.3	93.2	50.3	63.6
RUI	42.5	61.5	97.8	83.7	68.9	33.2	26.7
SCH	31.0	16.1		60.6	43.1		
Mean	32.5	32.4	57.0	44.3	43.2	40.8	48.6
SD	18.3	20.1	40.3	29.8	32.9	17.6	42.7
SE	7.5	8.2	16.5	12.2	13.4	7.2	17.4

DPD (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			-63.7
FRE	-5.4	-13.1	9.8
HUN	61.8	28.2	-6.0
JAG	-45.2	-57.8	97.0
RAY	5.1	89.0	31.3
RUI	96.9	12.0	-66.1
SCH	95.5	167.7	
Mean	34.8	37.7	0.4
SD	58.6	80.0	61.6
SE	23.9	32.7	25.1

DPD/Creatinine (nmol/nmol creat)

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			4.7			4.1	3.9
FRE	5.9	1.8	2.6	3.9	2.4	3.9	4.7
HUN	5.5	4.1	5.7	4.3	5.9	5.8	7.4
JAG	2.6	2.8	4.2	3.0	3.6	3.2	3.1
RAY	2.4	2.8	2.1	3.2	4.8	2.7	3.5
RUI	5.5	5.5	6.4	5.1	5.4	4.3	4.2
SCH	3.7	2.4		4.1	3.7		
Mean	4.3	3.2	4.3	3.9	4.3	4.0	4.5
SD	1.6	1.3	1.7	0.8	1.3	1.1	1.5
SE	0.6	0.5	0.7	0.3	0.5	0.4	0.6

DPD/Creatinine (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			-12.8
FRE	-33.9	33.3	50.0
HUN	-21.8	43.9	1.8
JAG	15.4	28.6	-23.8
RAY	33.3	71.4	28.6
RUI	-7.3	-1.8	-32.8
SCH	10.8	54.2	
Mean	-0.6	38.3	1.8
SD	25.1	24.9	32.0
SE	10.2	10.2	13.0

NTx (nmol • 24 hr^{-1})

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			1643.7			566.0	295.4
FRE	199.6	345.4	298.7	320.1	242.5	247.8	227.5
HUN	230.1	655.7	322.3	408.9	235.5	610.2	1000.4
JAG	1215.2	804.7	640.9	507.1	465.6	1125.5	667.8
RAY	496.5	332.0	375.5	589.1	566.5	514.8	479.8
RUI	459.2	924.9	1135.9	647.1	804.0	531.8	359.6
SCH	148.9	195.5		333.6	289.8		
Mean	458.3	543.0	736.2	467.7	434.0	599.4	505.1
SD	397.3	293.7	545.0	135.4	224.6	287.5	288.0
SE	162.2	119.9	222.5	55.3	91.7	117.4	117.6

NTx (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			-65.6
FRE	60.4	-29.8	-17.0
HUN	77.7	-64.1	89.3
JAG	-58.3	-42.1	75.6
RAY	18.7	70.6	37.1
RUI	40.9	-13.1	-53.2
SCH	124.0	48.2	
Mean	43.9	-5.0	11.0
SD	61.5	53.1	66.0
SE	25.1	21.7	26.9

NTx/Creatinine (nmol/nmol)

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			29.6			29.3	28.5
FRE	22.9	24.0	28.4	33.5	23.4	28.4	33.3
HUN	27.2	35.9	23.9	26.5	21.3	26.9	28.6
JAG	35.9	41.1	64.7	38.4	68.4	41.0	37.7
RAY	26.6	19.8	20.4	27.6	37.1	26.8	28.7
RUI	33.5	46.0	46.8	31.3	35.8	31.6	31.5
SCH	23.9	26.9		27.7	22.3		
Mean	28.3	32.3	35.6	30.8	34.7	30.7	31.4
SD	5.2	10.3	16.9	4.6	17.9	5.4	3.7
SE	2.1	4.2	6.9	1.9	7.3	2.2	1.5

NTx/Creatinine (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			-1.0
FRE	46.3	-2.5	0.0
HUN	-2.6	-40.7	12.6
JAG	7.0	66.4	-36.6
RAY	3.8	87.4	31.4
RUI	-6.6	-22.2	-32.5
SCH	15.9	-17.1	
Mean	10.6	11.9	-4.4
SD	19.1	52.2	26.2
SE	7.8	21.3	10.7

Pyridinium Crosslinks (nmol • 24 hr^{-1})

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			716.5			222.3	186.4
FRE	185.0	236.6	205.9	247.5	157.8	116.8	99.0
HUN	167.1	331.0	164.0	214.6	148.5	310.5	653.9
JAG	496.8	286.0	172.0	194.0	123.6	361.7	207.7
RAY	140.2	209.0	206.7	252.4	294.1	239.1	211.5
RUI	222.5	277.8	405.2	317.8	295.9	314.9	155.7
SCH	98.2	86.0		166.1	195.7		
Mean	218.3	237.7	311.7	232.1	202.6	260.9	252.4
SD	142.7	85.4	217.3	53.1	75.2	87.5	201.1
SE	58.3	34.9	88.7	21.7	30.7	35.7	82.1

Pyridinium Crosslinks (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			-69.0
FRE	33.8	-33.3	-43.3
HUN	28.4	-55.1	89.3
JAG	-61.0	-56.8	110.3
RAY	80.0	40.7	15.7
RUI	42.8	6.5	-22.3
SCH	69.1	127.6	
Mean	32.2	4.9	13.5
SD	49.9	71.0	72.7
SE	20.4	29.0	29.7

Pyridinium Crosslinks/Creatinine (nmol/nmol)

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			12.9			11.5	18.0
FRE	21.2	16.5	19.5	25.9	15.2	13.4	14.5
HUN	19.8	18.1	12.2	13.9	13.4	13.7	18.7
JAG	14.7	14.6	17.4	14.7	18.2	13.2	11.7
RAY	7.5	12.5	11.2	11.8	19.3	12.4	12.7
RUI	16.2	13.8	16.7	15.4	13.2	18.7	13.7
SCH	15.7	11.8		13.8	14.6		
Mean	15.9	14.6	15.0	15.9	15.7	13.8	14.9
SD	4.8	2.4	3.3	5.0	2.5	2.5	2.9
SE	2.0	1.0	1.4	2.1	1.0	1.0	1.2

Pyridinium Crosslinks/Creatinine (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			-10.9
FRE	22.2	-7.9	-31.3
HUN	-29.8	-26.0	12.3
JAG	0.0	24.7	-24.1
RAY	57.3	54.4	10.7
RUI	-4.9	-4.3	12.0
SCH	-12.1	23.7	
Mean	5.4	10.8	-5.2
SD	30.5	28.9	19.6
SE	12.5	11.8	8.0

Hydroxyproline (mol • 24 hr^{-1})

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			257.0			74.3	40.8
FRE	15.8	55.2	54.7	44.4	52.3	44.8	40.3
HUN	47.0	80.1	40.2	51.6	50.9	105.8	141.9
JAG	297.2	146.9	68.3	99.7	48.6	137.2	127.2
RAY	96.8	55.2	54.5	122.8	94.2	74.0	80.0
RUI	83.8	96.0	98.3	73.2	96.4	88.3	89.3
SCH	18.3	54.1		69.7	58.4		
Mean	93.2	81.3	95.5	76.9	66.8	87.4	86.6
SD	105.3	36.4	81.5	29.6	22.3	31.6	42.4
SE	43.0	14.9	33.3	12.1	9.1	12.9	17.3

Hydroxyproline (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			-71.1
FRE	181.0	-5.3	-18.1
HUN	9.8	-36.5	163.2
JAG	-66.5	-66.9	100.9
RAY	26.9	70.7	35.8
RUI	-12.6	0.4	-10.2
SCH	280.9	7.9	
Mean	69.9	-4.9	33.4
SD	132.5	46.4	85.9
SE	54.1	18.9	35.1

Hydroxyproline/Creatinine (mol • g^{-1})

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			41.0			34.0	34.8
FRE	16.0	34.0	46.0	41.1	44.6	45.5	52.2
HUN	49.2	38.8	26.4	29.6	40.7	41.2	35.9
JAG	77.7	66.4	61.0	66.9	63.1	44.2	63.5
RAY	45.9	29.2	26.2	51.0	54.6	34.0	42.2
RUI	54.1	42.2	35.9	31.3	38.0	46.4	69.3
SCH	26.0	65.8		51.2	38.5		
Mean	44.8	46.1	39.4	45.2	46.6	40.9	49.7
SD	21.8	16.1	13.2	14.1	10.1	5.6	14.5
SE	8.9	6.6	5.4	5.8	4.1	2.3	5.9

Hydroxyproline/Creatinine (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			-17.1
FRE	156.9	31.2	-1.1
HUN	-39.8	4.9	56.1
JAG	-13.9	-5.0	-27.5
RAY	11.1	87.0	29.8
RUI	-42.1	-10.0	29.2
SCH	96.9	-41.5	
Mean	28.2	11.1	11.6
SD	81.1	44.0	32.0
SE	33.1	18.0	13.1

Calcium (mg • 24 hr–1)

Subject	PRE Training			POST Training			POST Study
	passive	exercise	combined	passive	exercise	combined	
FLE			301			145	105
FRE	114	656	95	111	144	85	84
HUN	306	239	172	50	148	270	248
JAG	389	57	46	242	70	113	233
RAY	92	98	113	202	195	237	120
RUI	92	444	462	66	429	575	236
SCH	79	104		59	56		
Mean	179	266	198	122	174	238	171
SD	134	238	156	81	135	180	76
SE	55	97	64	33	55	74	31

Calcium (% change)

Subject	% Change PRE to POST Training		
	passive	exercise	combined
FLE			-52
FRE	-3	-78	-11
HUN	-84	-38	57
JAG	-38	23	146
RAY	120	99	110
RUI	-28	-3	24
SCH	-25	-46	
Mean	-10	-7	46
SD	69	63	74
SE	28	26	30

MRI Muscle Volume (cm^3)

PRE Exercise Training

Subject	R. Femoris		V. Lateralis		V. Intermedius		V. Medialis	
	Left	Right	Left	Right	Left	Right	Left	Right
RUI	297	294	919	895	542	619	609	646
RAY	347	358	1061	993	705	657	608	593
FRE	242	242	779	718	510	544	511	535
HUN	333	333	876	876	565	565	585	585
JAG	375	382	784	733	679	642	540	532
FLE	229	229	663	663	504	504	438	438
Mean	304	306	847	813	584	589	549	555
SD	59	62	137	127	87	60	67	71
SE	24	25	56	52	35	25	27	29

PRE Combined Training

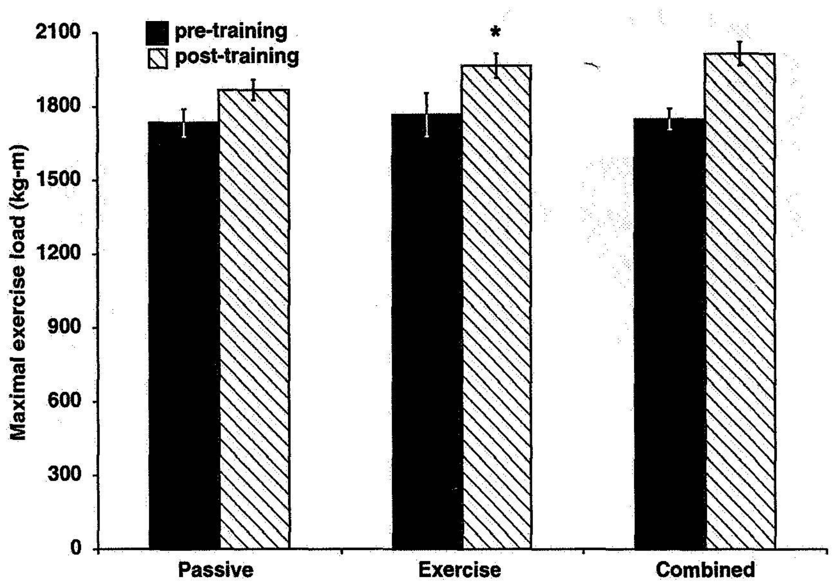
RUI	312	308	904	881	588	671	651	679
RAY	273	289	816	778	532	506	463	454
FRE	267	265	843	788	562	597	562	561
HUN	334	334	873	873	589	589	583	583
JAG	359	372	748	683	687	657	534	511
FLE	230	230	705	705	530	530	429	429
Mean	296	300	815	785	581	592	537	536
SD	48	50	76	82	58	66	81	92
SE	19	21	31	34	24	27	33	37

POST Combined Training

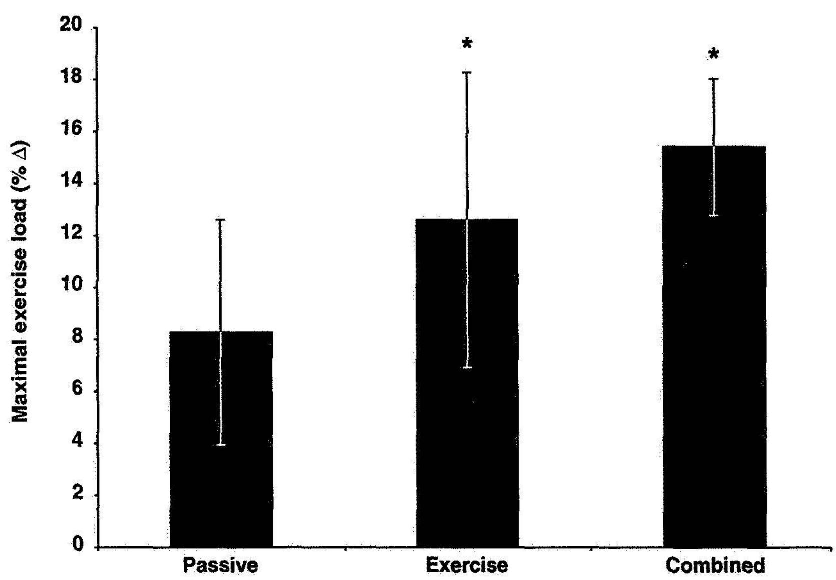
RUI	320	325	954	959	625	701	647	714
RAY	277	298	798	834	548	540	498	491
FRE	293	290	887	853	603	602	563	590
HUN	359	359	887	887	601	601	590	590
JAG	382	396	807	704	752	684	520	505
FLE	246	246	710	710	559	559	470	470
Mean	313	319	841	825	615	615	548	560
SD	51	53	86	101	73	65	65	91
SE	21	22	35	41	30	27	27	37

APPENDIX G

Fig. 12. Mean (±SE) supine maximal exercise load for the three Phases.

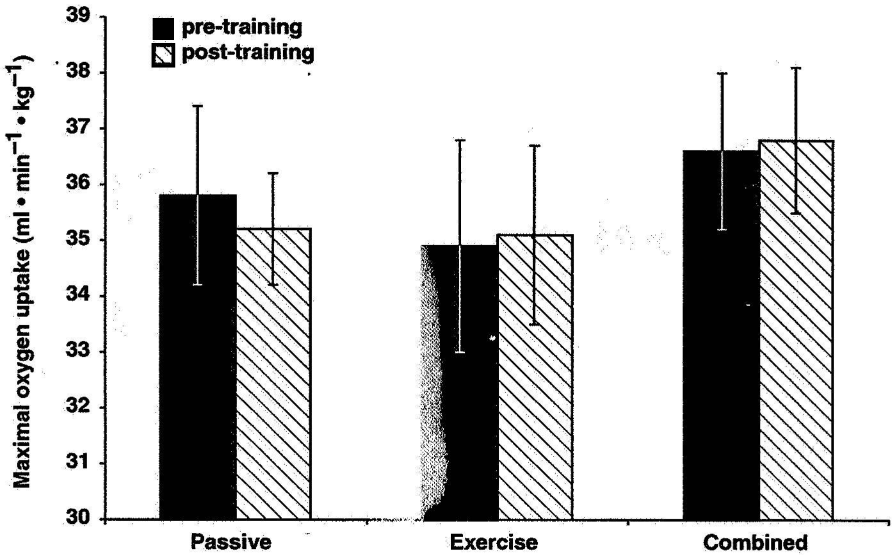


*a) Pre- versus post-training, kg-m. * P < 0.05 from pre-training.*

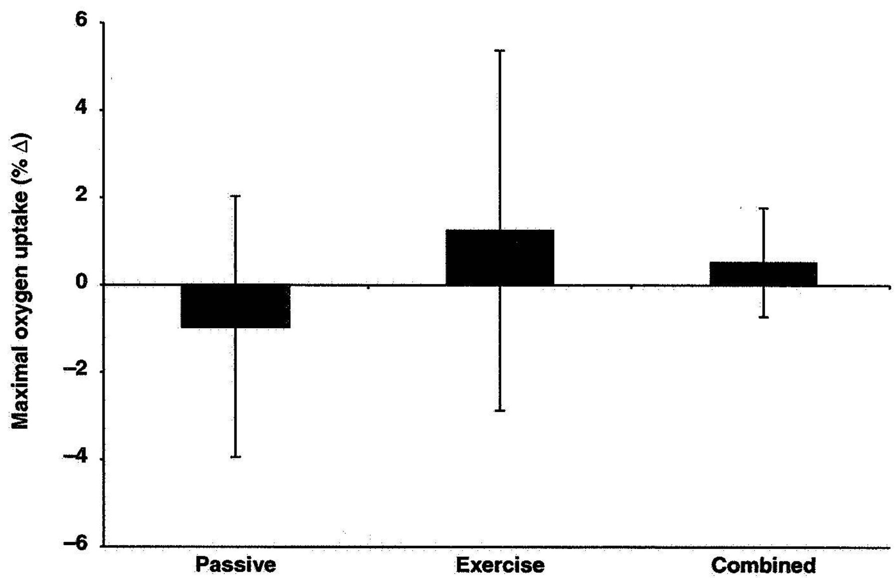


*b) After training, percent change. * P < 0.05 from zero.*

Fig 13. Mean (±SE) supine maximal oxygen uptake for the three Phases.

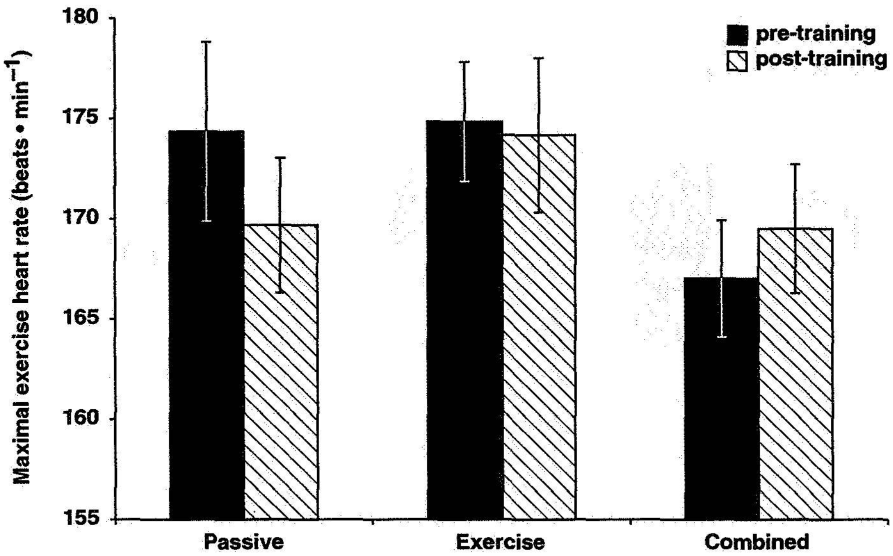


a) Pre- versus post-training, ml • min^{-1} • kg^{-1}.

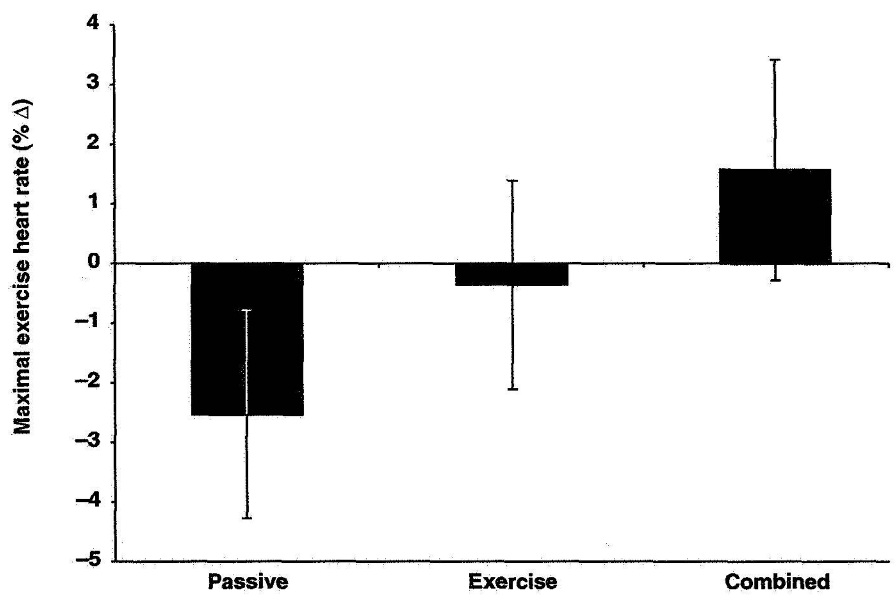


b) After training, percent change.

Fig. 14. Mean (±SE) supine maximal heart rate for the three Phases.

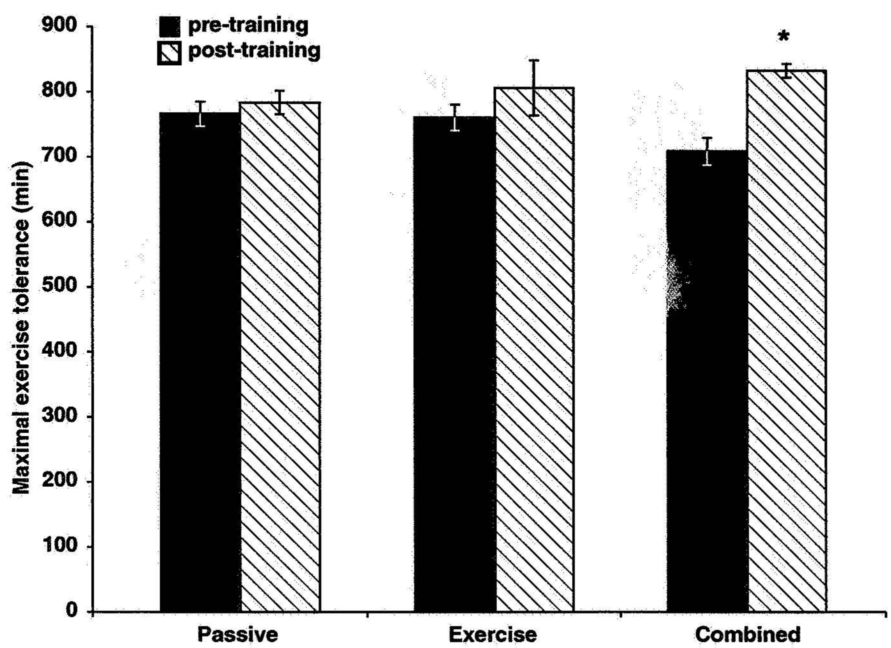


a) Pre- versus post-training, beats • min^{-1}.

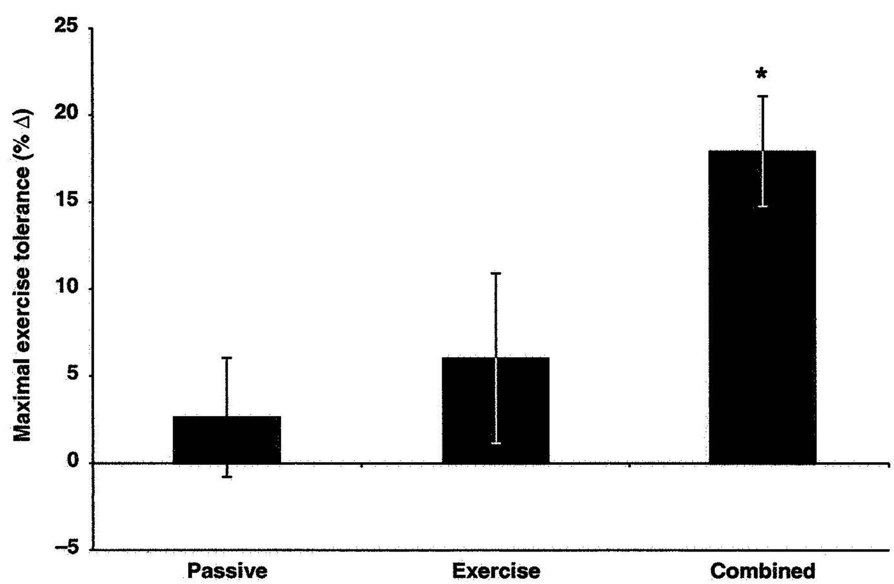


b) After training, percent change.

Fig. 15. Mean (±SE) supine maximal exercise tolerance for the three Phases.

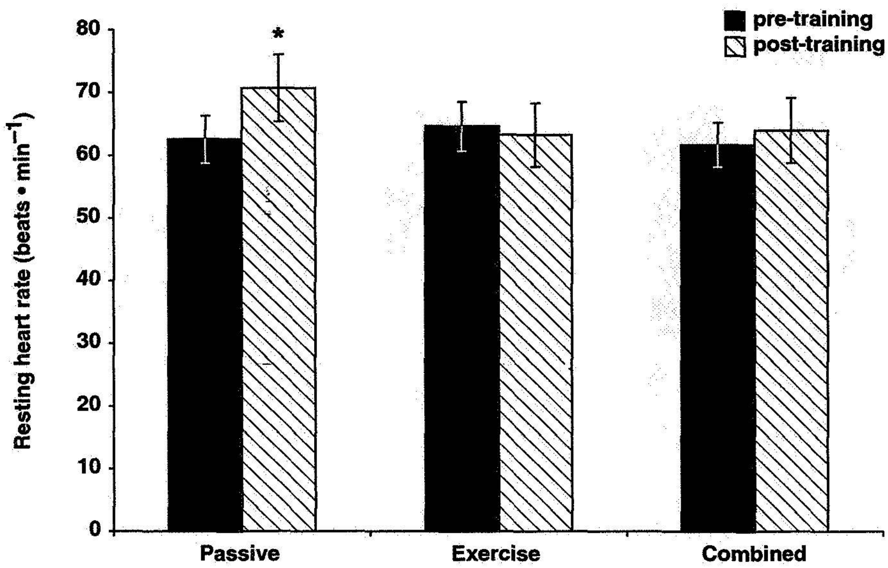


*a) Pre- versus post-training, min. * P < 0.05 from pre-training.*

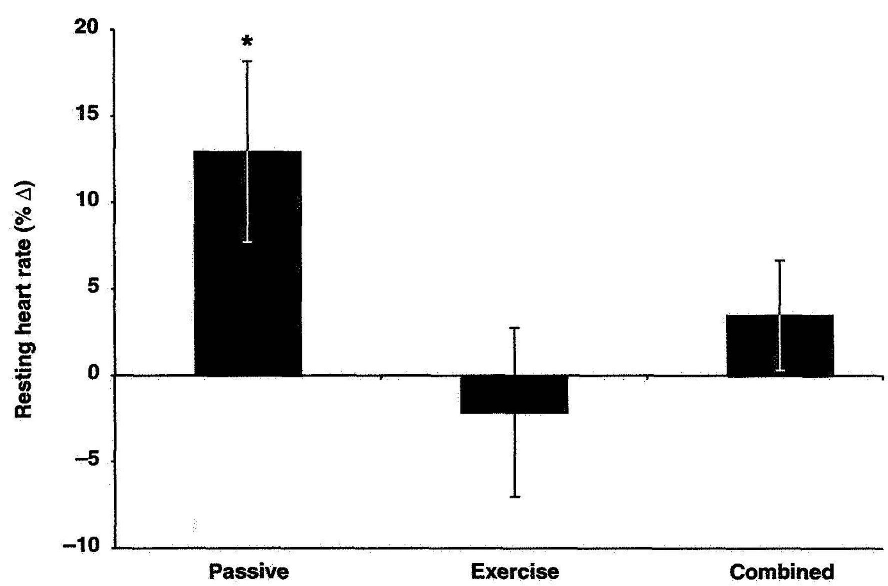


*b) After training, percent change. * P < 0.05 from zero.*

Fig. 16. Mean (±SE) resting pre-tilt heart rate for the three Phases.

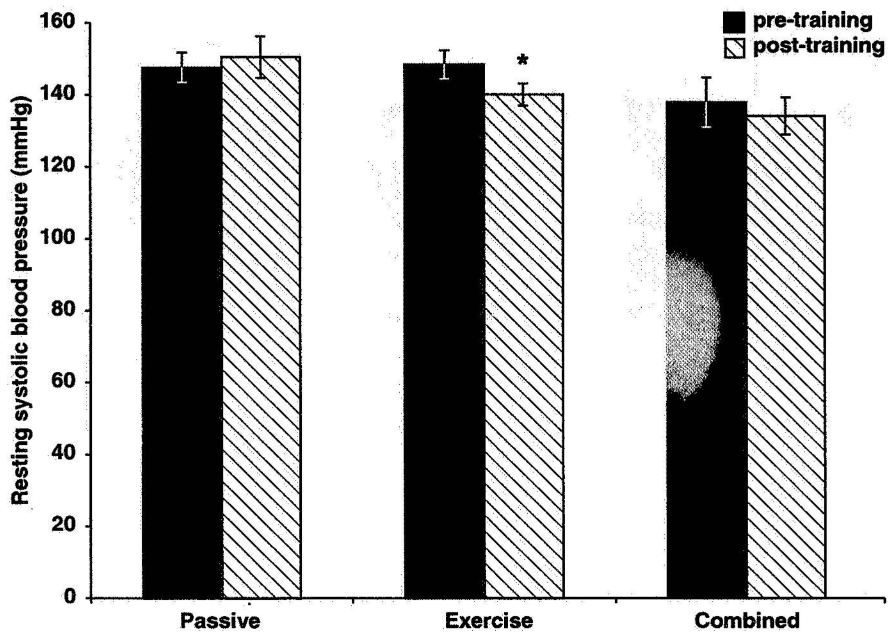


a) Pre- versus post- training, beats • min^{-1}. P < 0.05 from pre-training.

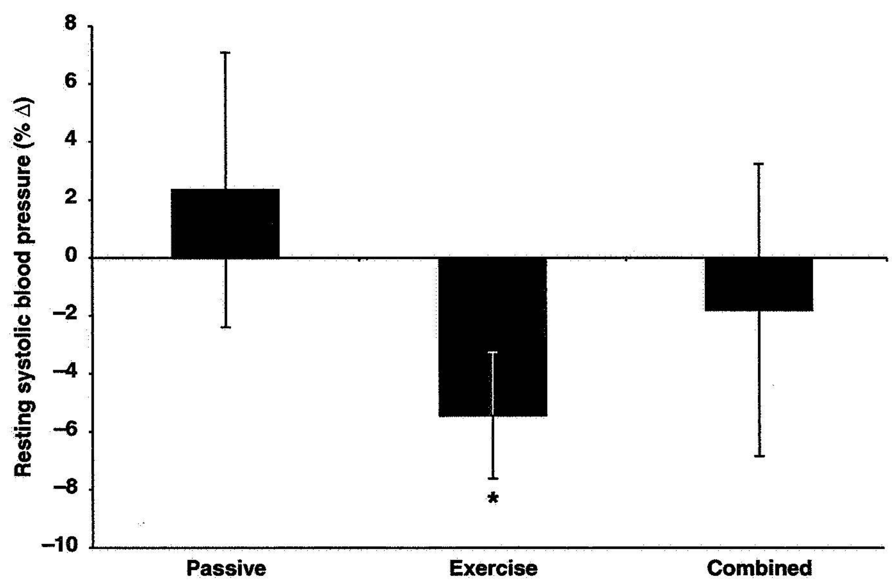


*b) After training, percent change. * P < 0.05 from zero.*

Fig. 17. Mean (±SE) resting pre-tilt systolic blood pressure for the three Phases.

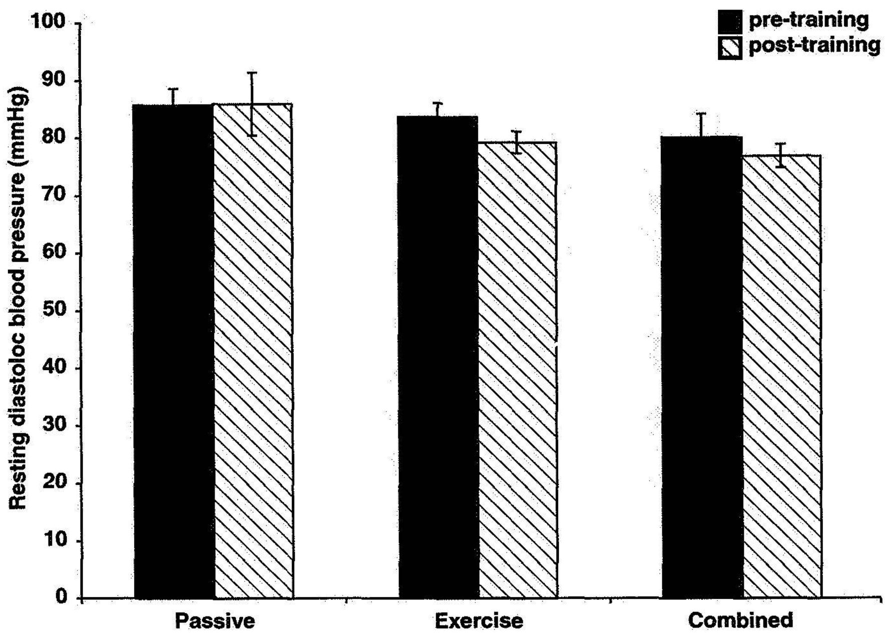


*a) Pre- versus post-training, mmHg. * P < 0.05 from pre-training.*

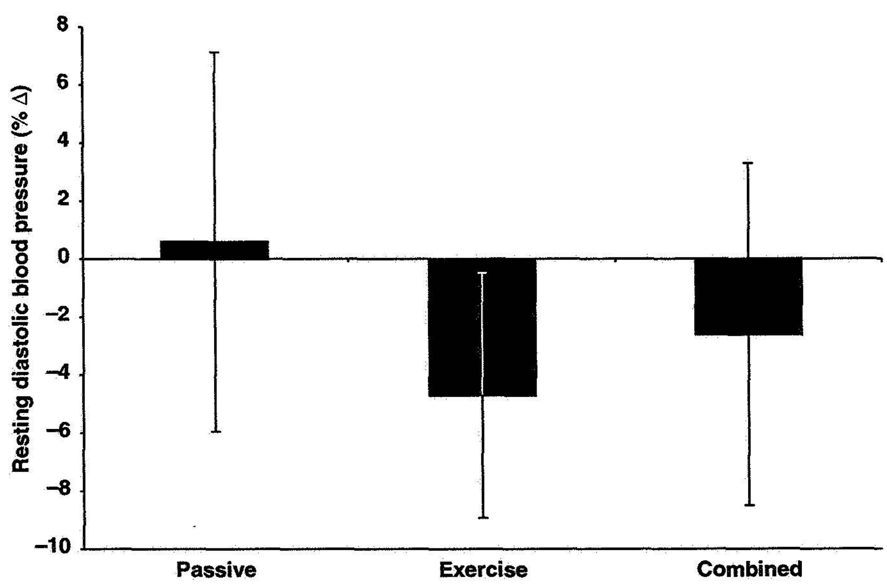


*b) After training, percent change. * P < 0.05 from zero.*

Fig 18. Mean (±SE) resting pre-tilt diastolic blood pressure for the three Phases.

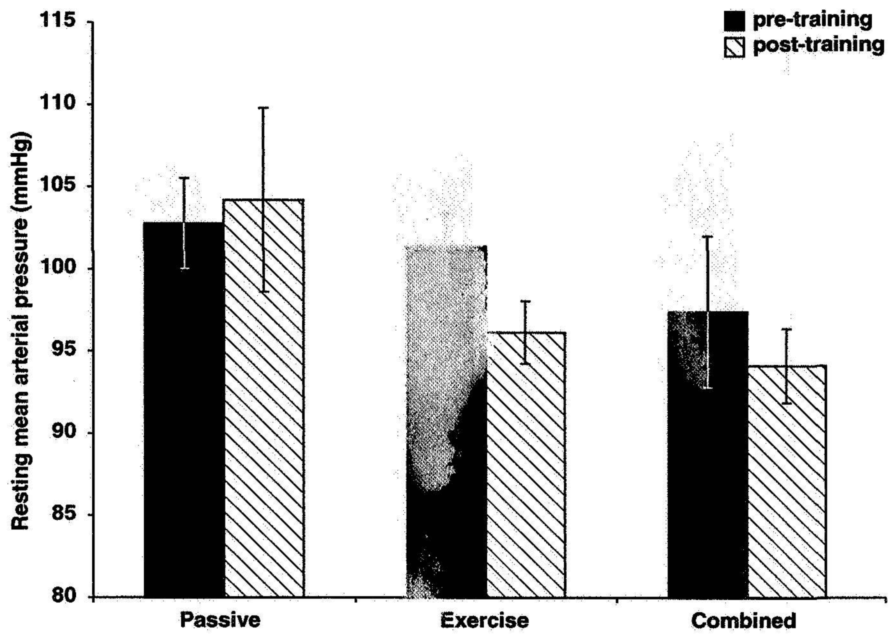


a) Pre- versus post-training, mmHg.

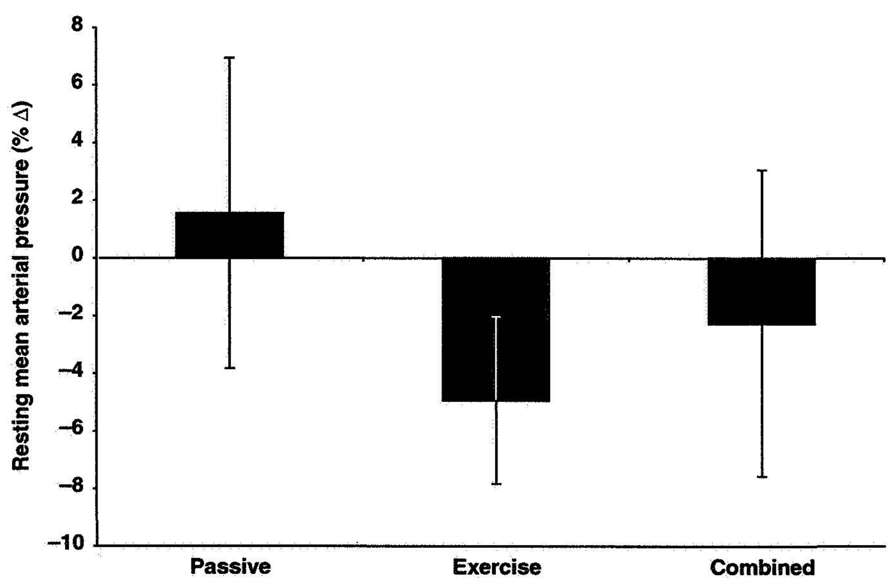


b) After training, percent change.

Fig. 19. Mean (±SE) resting pre-tilt mean arterial pressure for the three Phases.

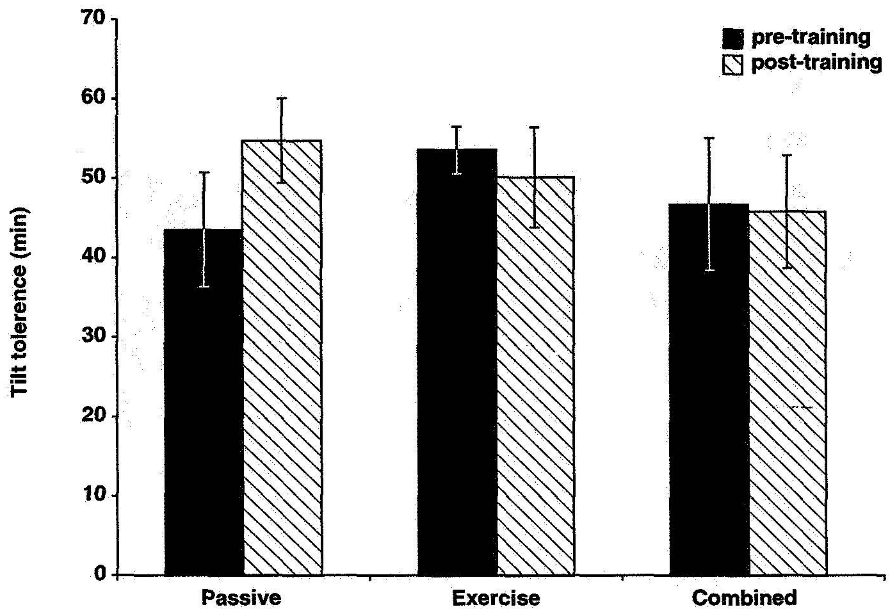


a) Pre- versus post-training, mmHg.

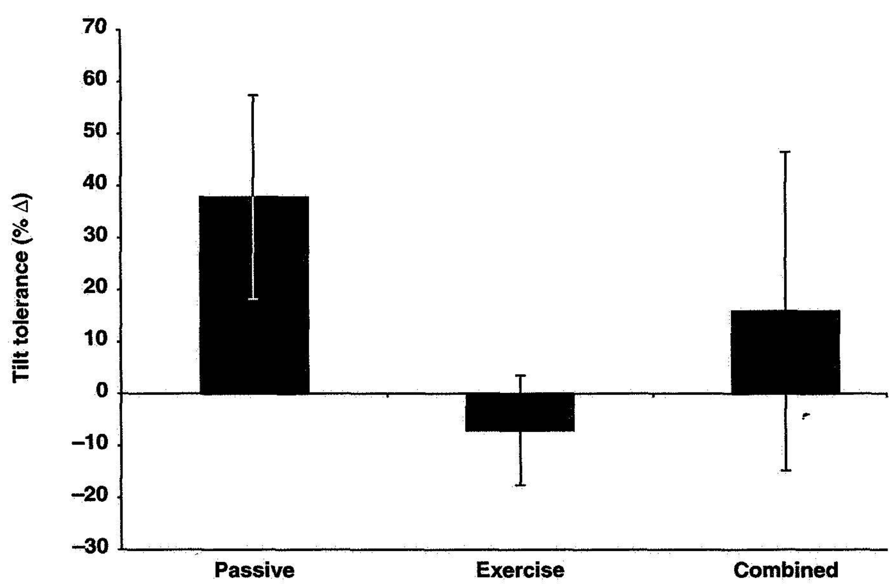


b) After training, percent change.

Fig. 20. Mean (±SE) tilt-tolerance time for the three Phases.

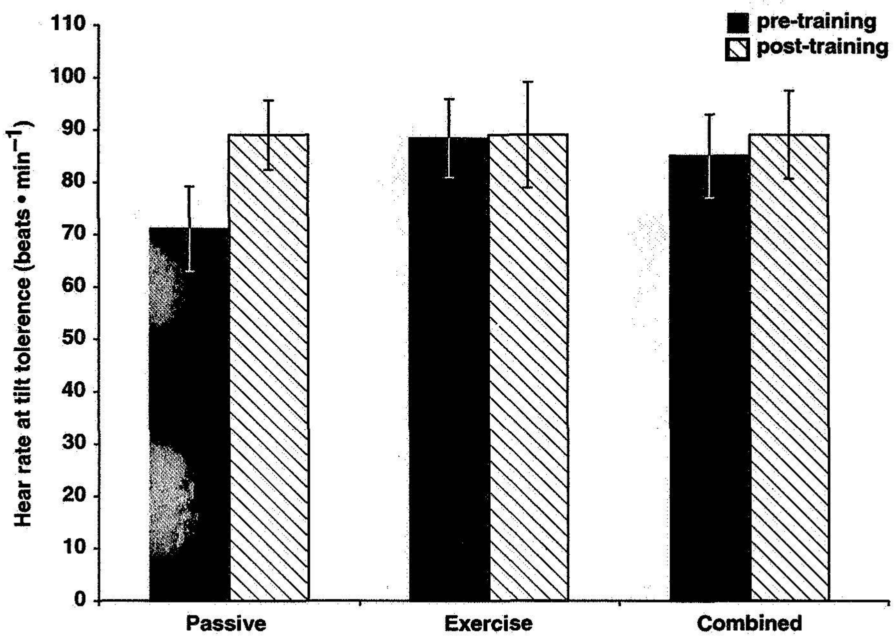


a) Pre- versus post-training, min.

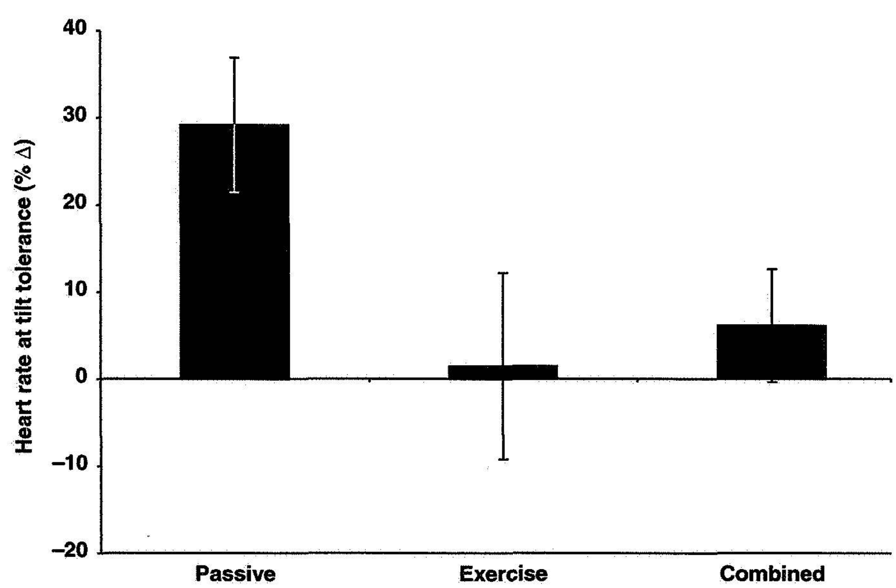


b) After training, percent change.

Fig. 21. Mean (±SE) heart rate at tilt-tolerance for the three Phases.

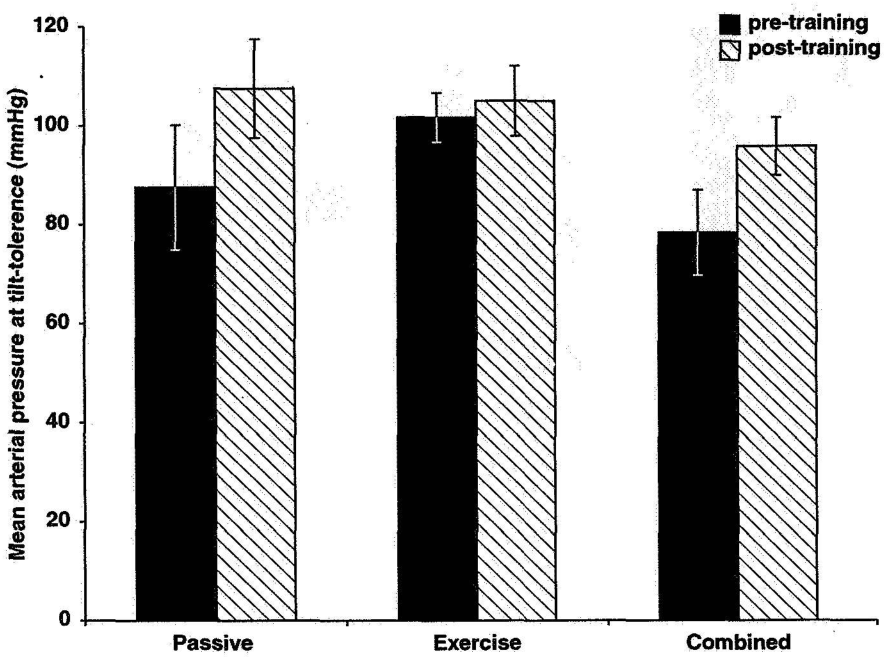


a) Pre- versus post-training, beats • min^{-1}.

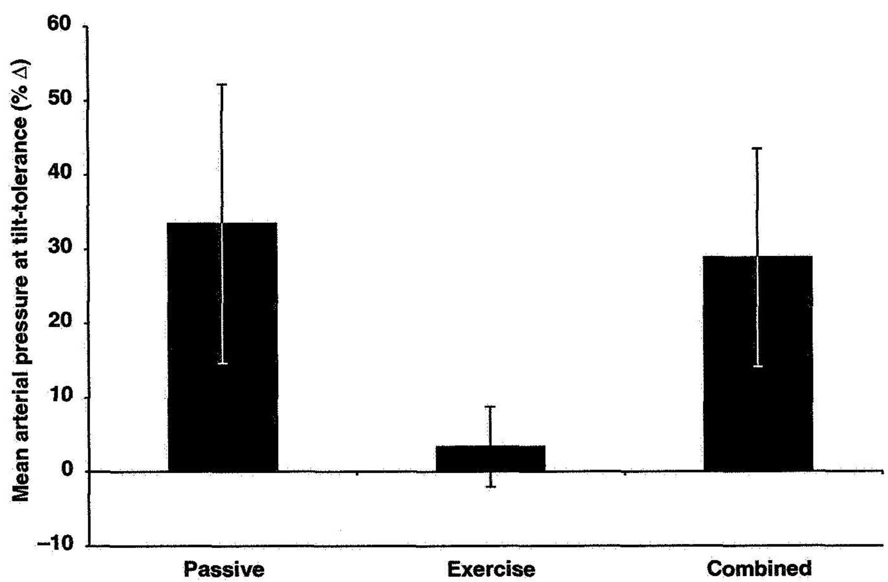


b) After training, percent change.

Fig. 22. Mean (±SE) arterial pressure at tilt-tolerance for the three Phases.



a) Pre- versus post-training, mmHg.



b) After training, percent change.

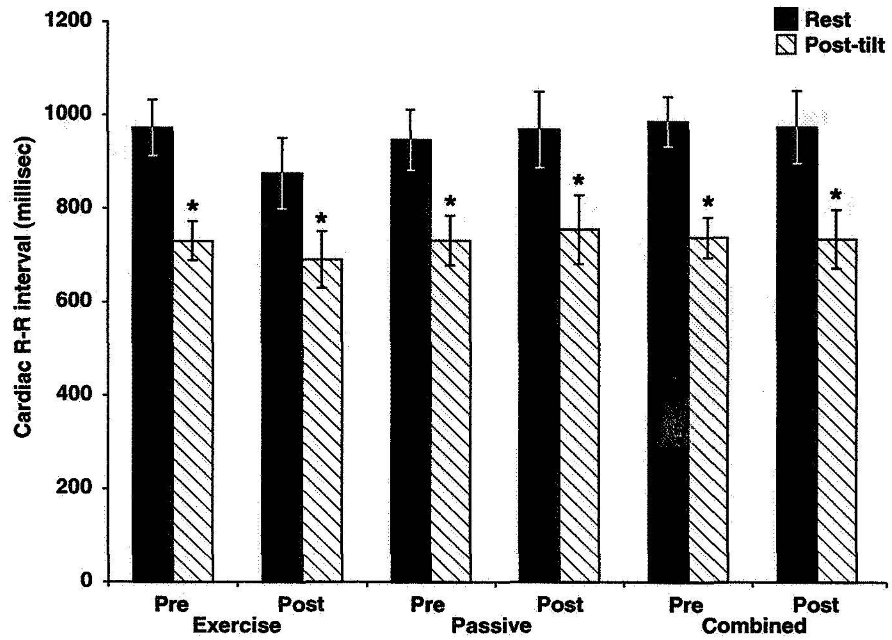


*Fig 23. Mean (±SE) cardiac R-R interval at rest and post-tilt, pre- and post-training for the three Phases. * P < 0.05 from corresponding rest value.*

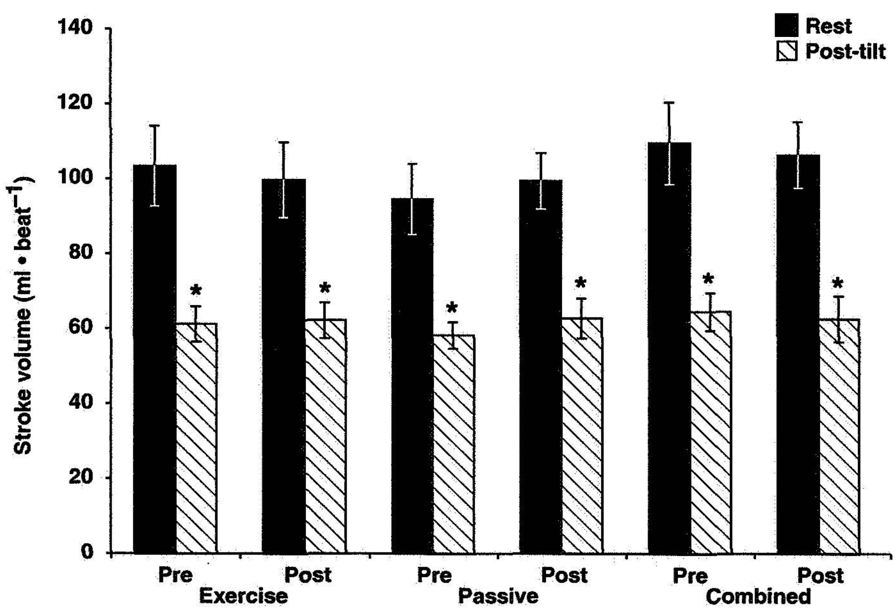


*Fig. 24. Mean (±SE) stroke volume at rest and post-tilt, pre- and post-training for the three Phases. * P < 0.05 from corresponding rest value.*

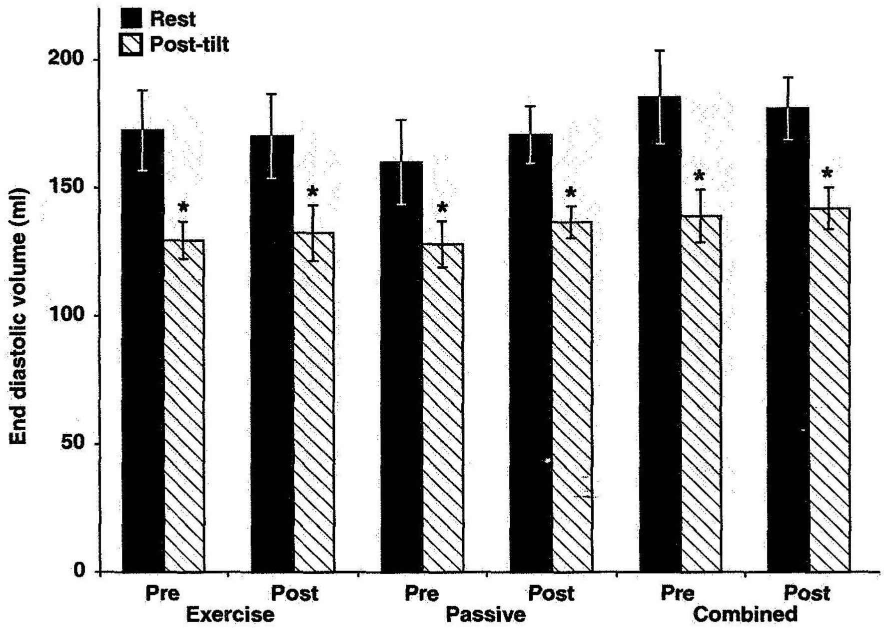


*Fig. 25. Mean (±SE) end-diastolic volume at rest and post-tilt, pre- and post-training for the three Phases. * P < 0.05 from corresponding rest value.*

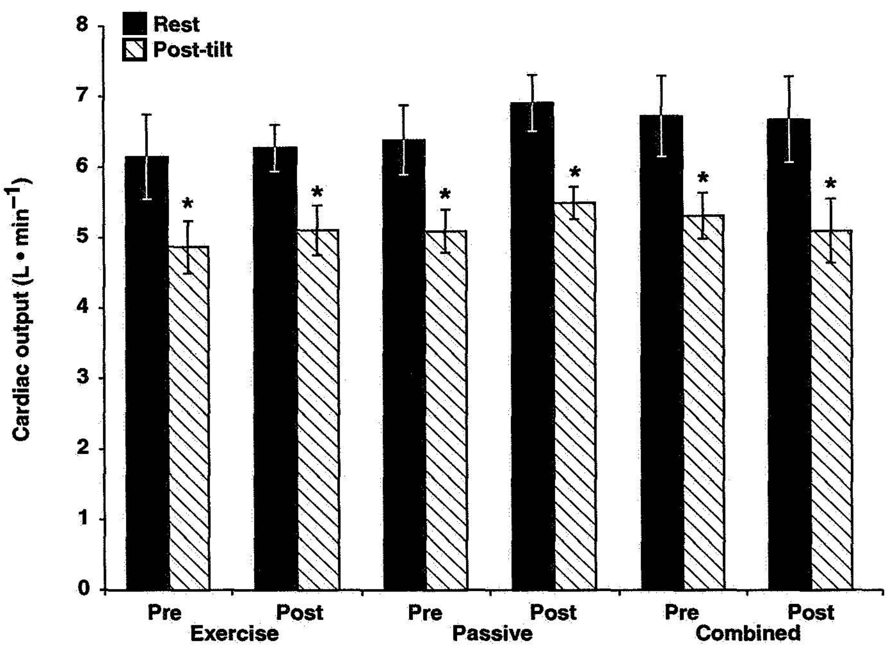


*Fig 26. Mean (±SE) cardiac output at rest and post-tilt, pre- and post-training for the three Phases. * P < 0.05 from corresponding rest value.*

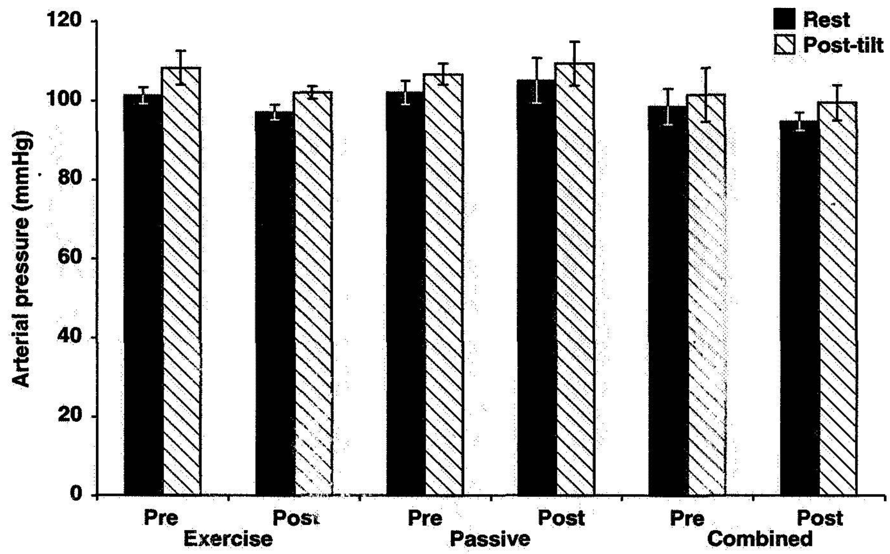


Fig 27. Mean (±SE) Finapress arterial pressure at rest and post-tilt, pre-and post-training for the three Phases.

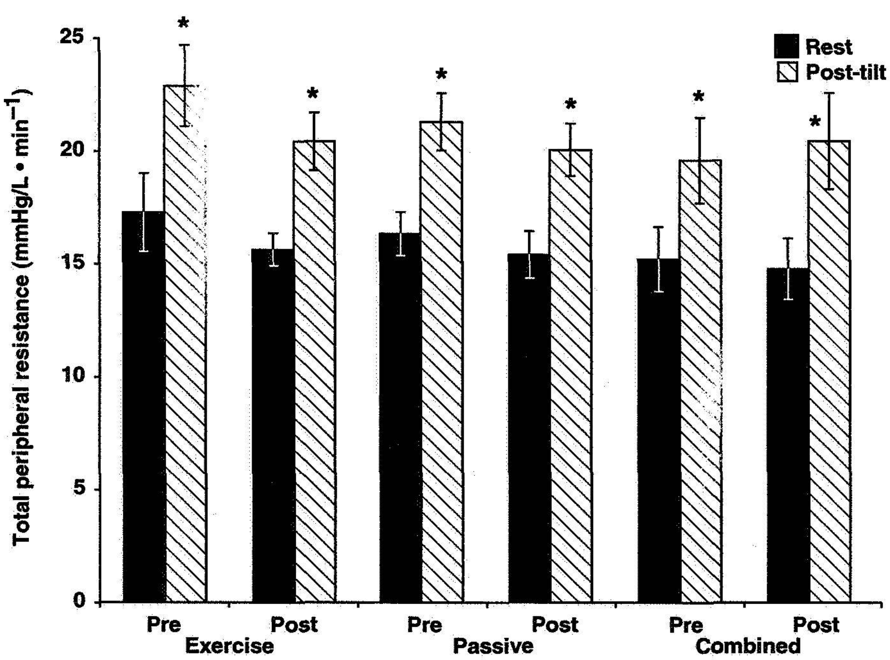
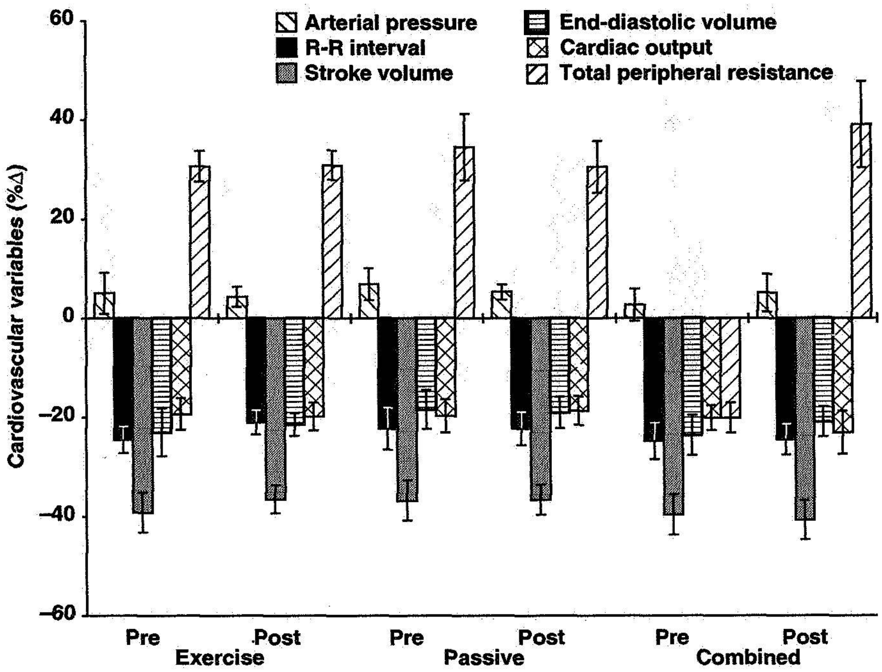
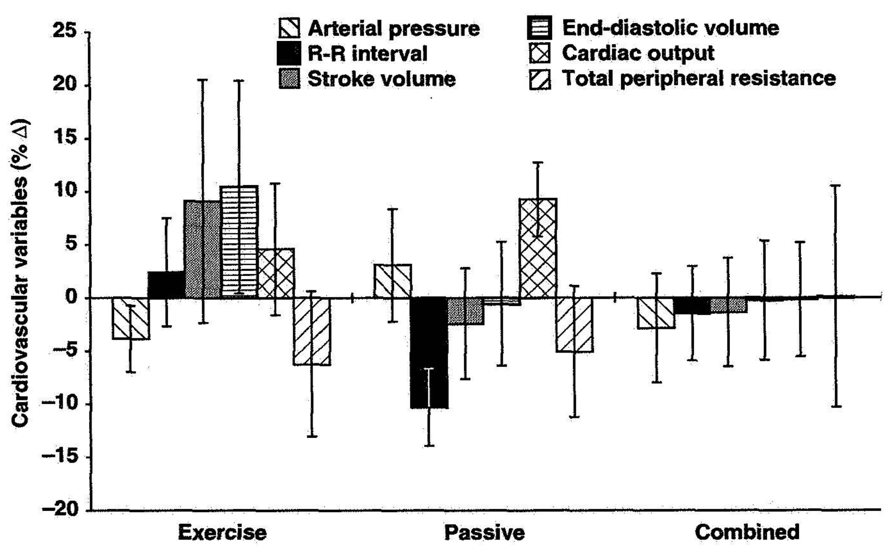


*Fig 28. Mean (±SE) total peripheral resistance at rest and post-tilt, pre- and post-training for the three Phases. * $P < 0.05$ from corresponding rest value.*

Fig 29. Mean (±SE) cardiovascular variables pre- and post-training for the three Phases.

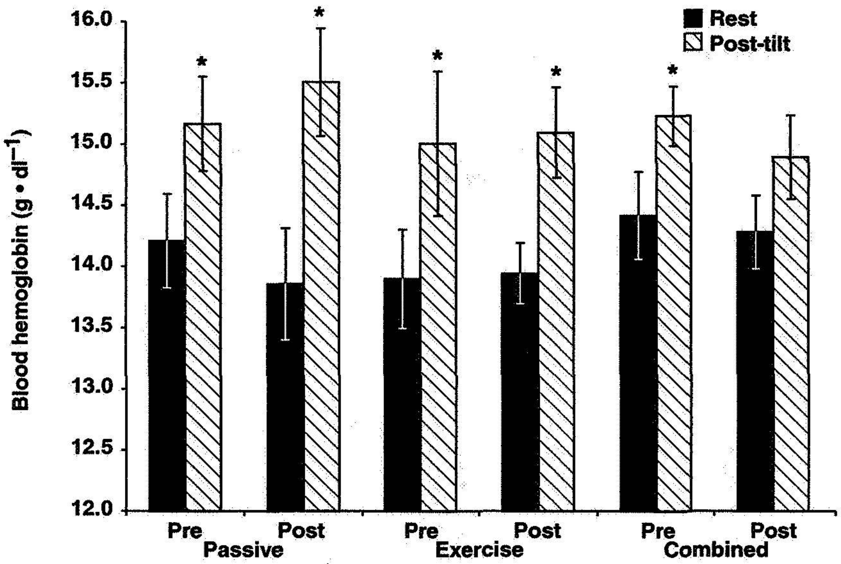


a) Rest versus tilt-tolerance, percent change.

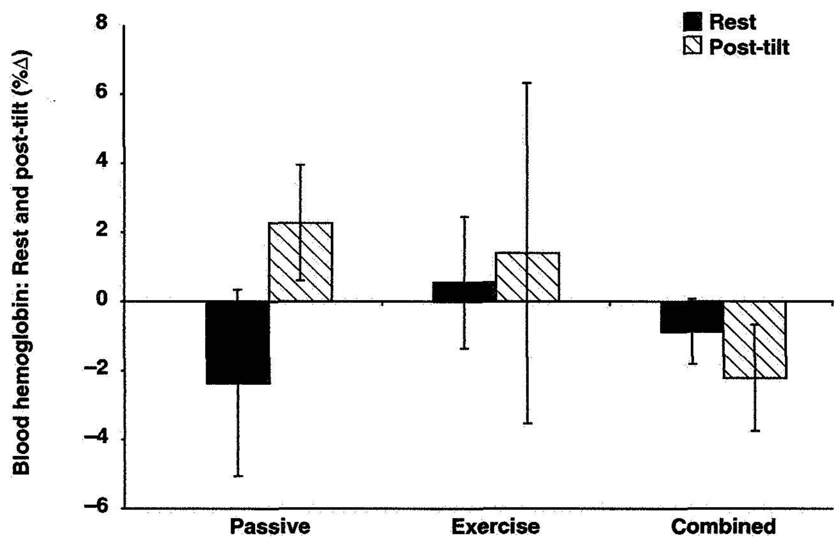


b) Pre-tilt, percent change.

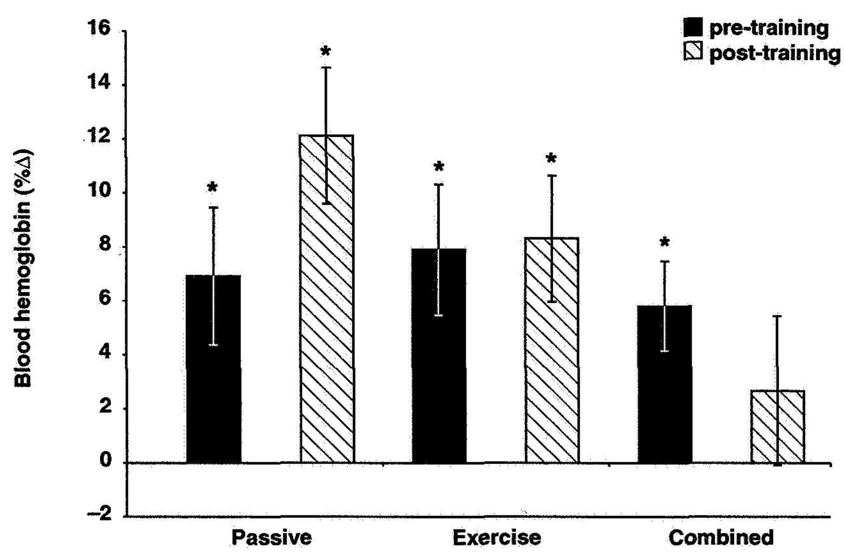
Fig 30. Mean (±SE) blood hemoglobin at rest and post-tilt for the three Phases.



*a) Pre- versus post-training, g • dl^{-1}. * $P < 0.05$ from corresponding rest value.*

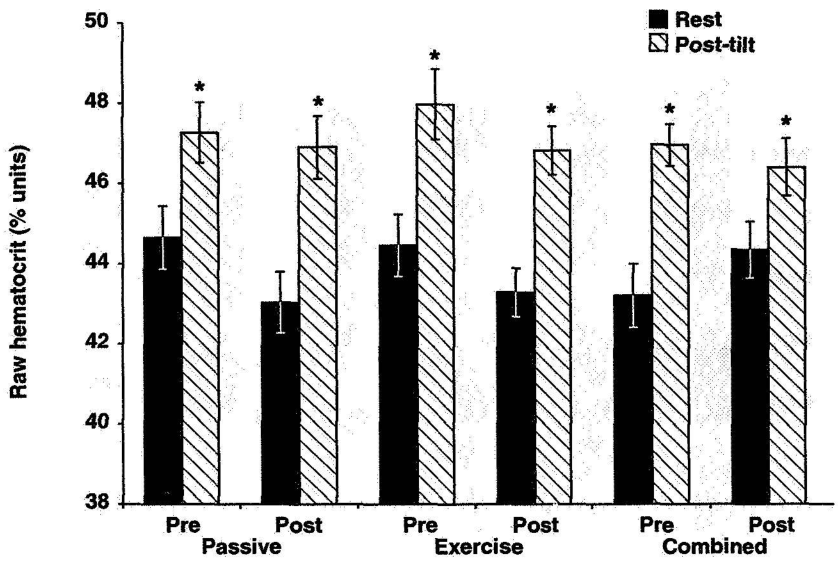


b) After training, percent change.

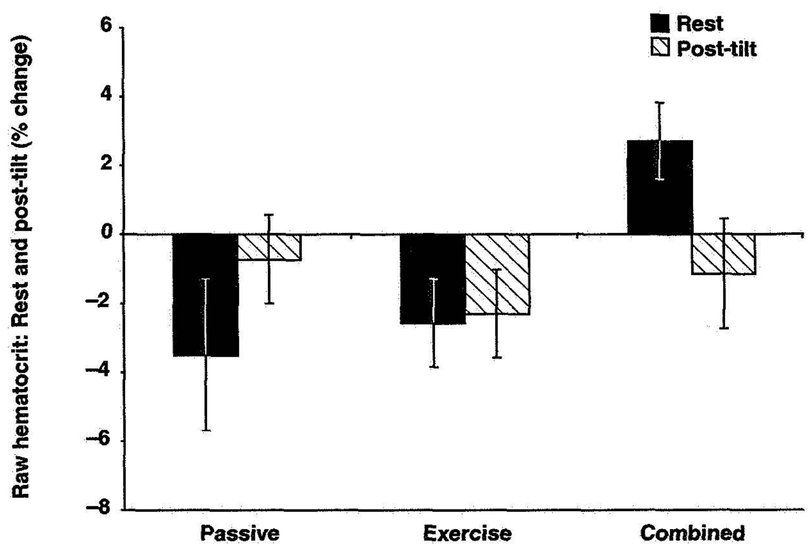


*c) Pre- versus post-training, percent change. * $P < 0.05$ from zero.*

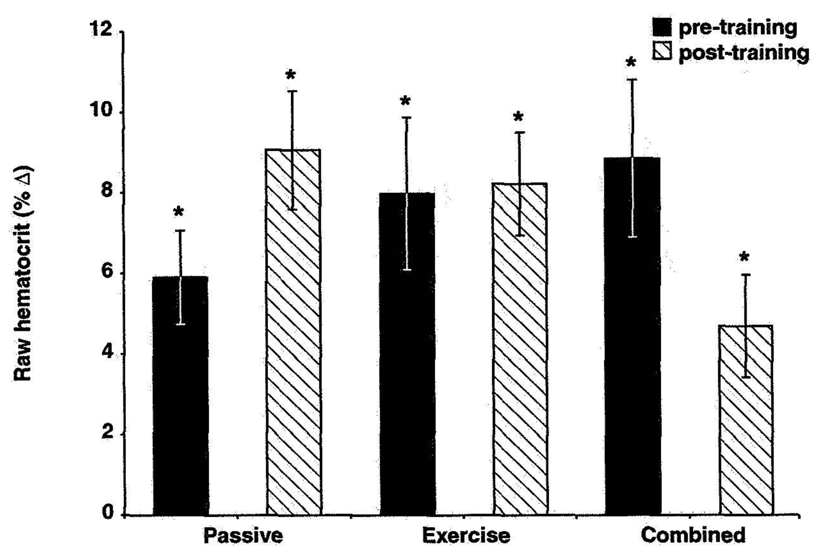
Fig. 31. Mean (±SE) raw hematocrit at rest and post-tilt for the three Phases.



*a) Pre- versus post-training, percent units. * P < 0.05 from corresponding rest value.*

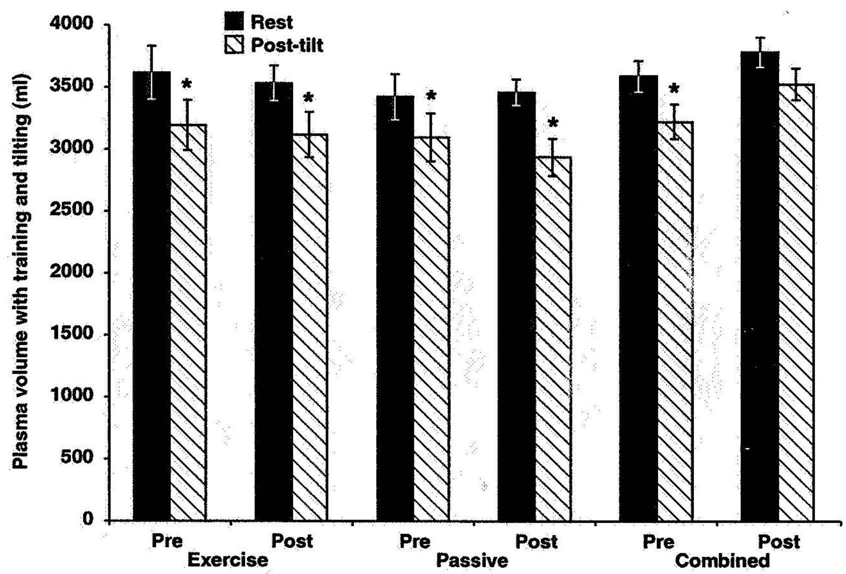


b) After training, percent change.

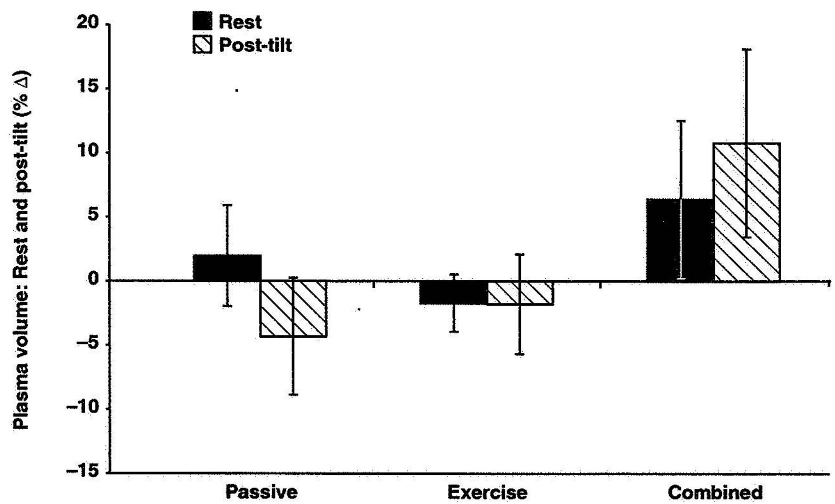


*c) Pre- versus post-training, percent change. * P < 0.05 from zero.*

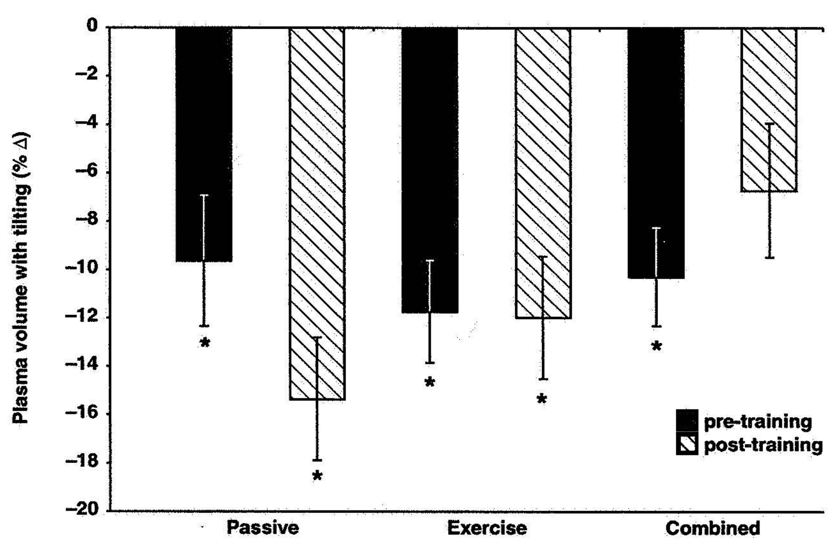
Fig 32. Mean (±SE) absolute plasma volume at rest and post-tilt for the three Phases.



*a) Pre- versus post-training, ml. * P < 0.05 from corresponding rest value.*

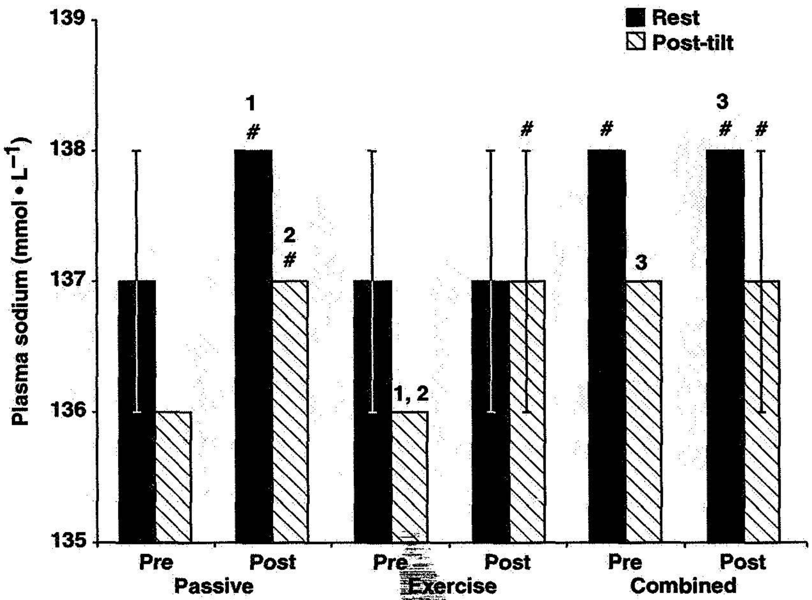


b) After training, percent change.

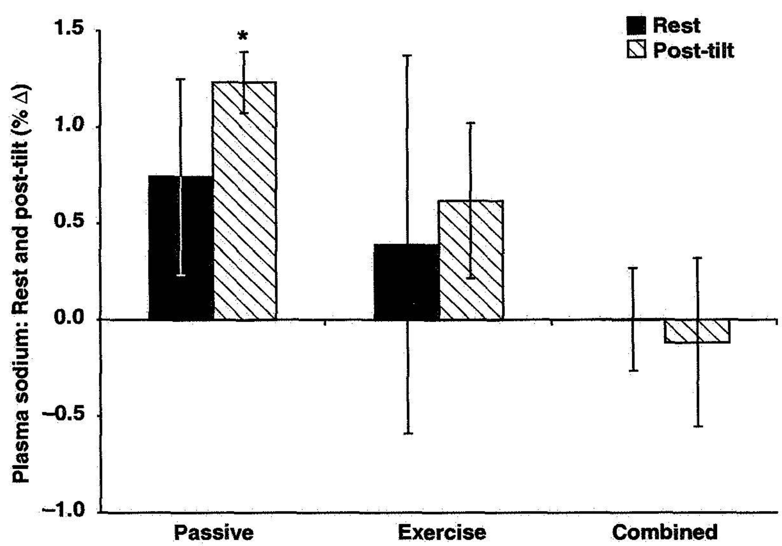


*c) Pre- versus post-training, percent change. * P < 0.05 from zero.*

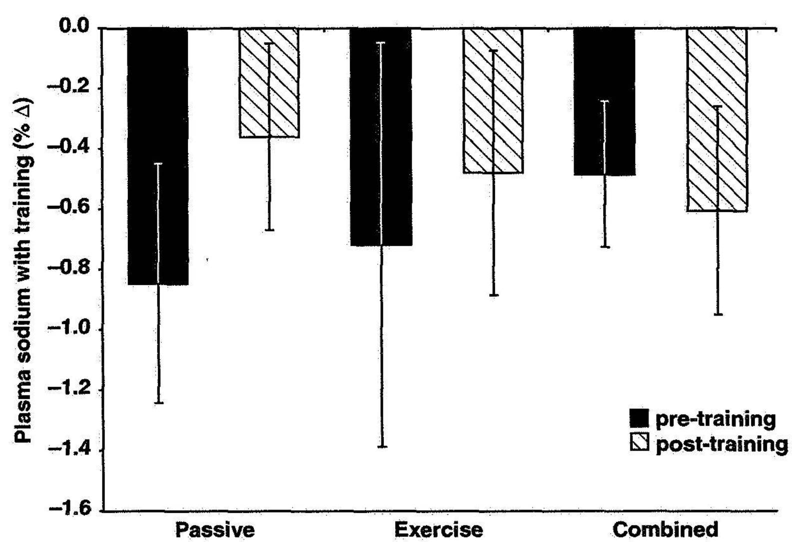
Fig. 33. Mean (±SE) plasma sodium concentration at rest and post-tilt for the three Phases. Normal range is 136 – 145 mmol • L^{-1}.



a) Pre- versus post-training, mmol • L^{-1}. # $P < 0.05$ from comparable pre-passive; 1, 2, 3 are $P < 0.05$ pairs of different values.

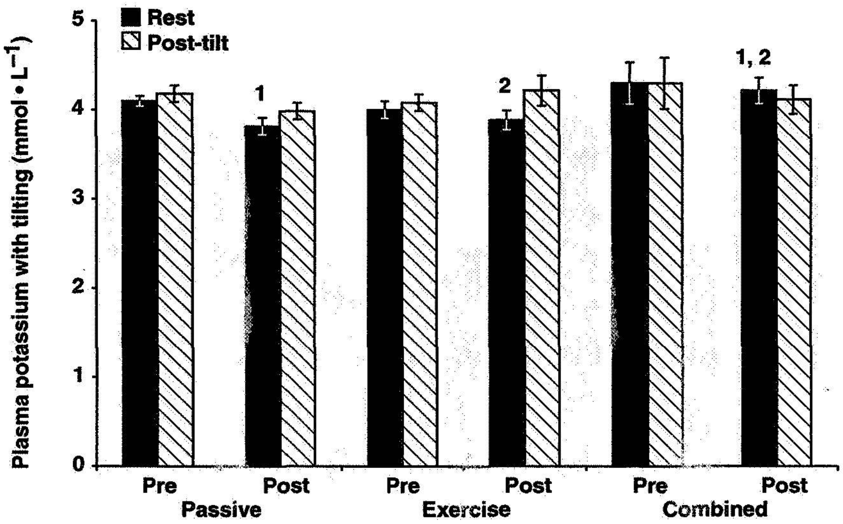


*b) After training, percent change. * $P < 0.05$ from zero.*

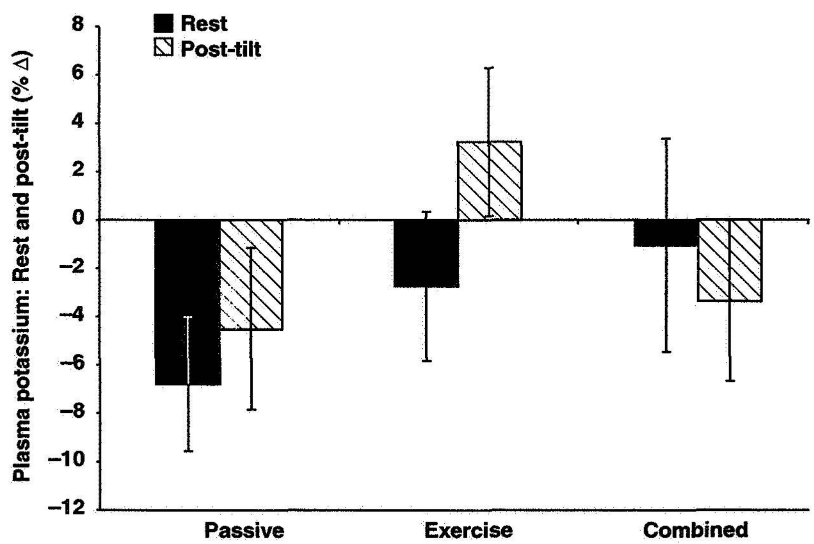


c) Pre- versus post-training, percent change.

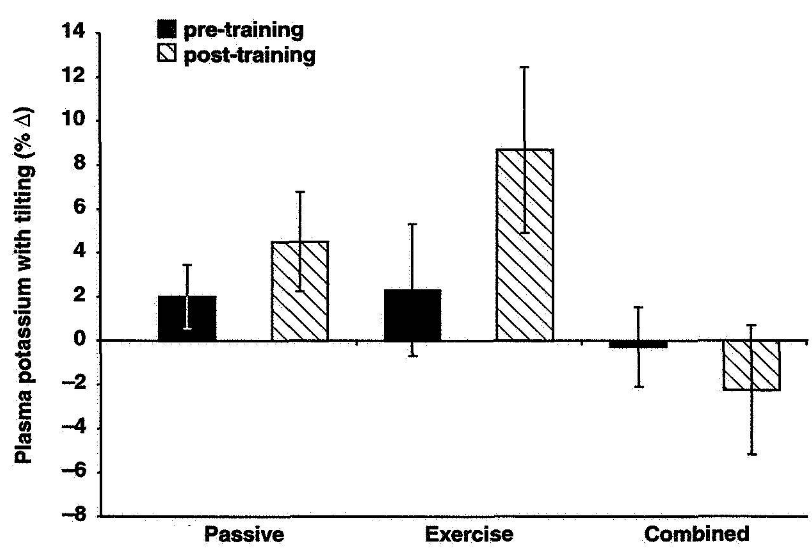
Fig. 34. Mean (±SE) plasma potassium concentration at rest and post-tilt for the three Phases. Normal range is 3.6 – 5.6 mmol • L^{-1}.



a) Pre- versus post-training, mmol • L^{-1}. 1, 2 are $P < 0.05$ pairs of different values.

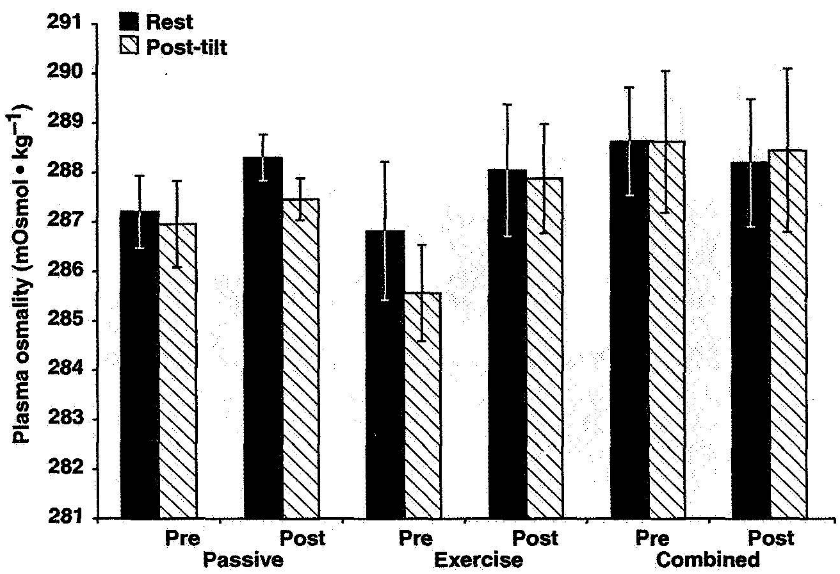


b) After training, percent change.

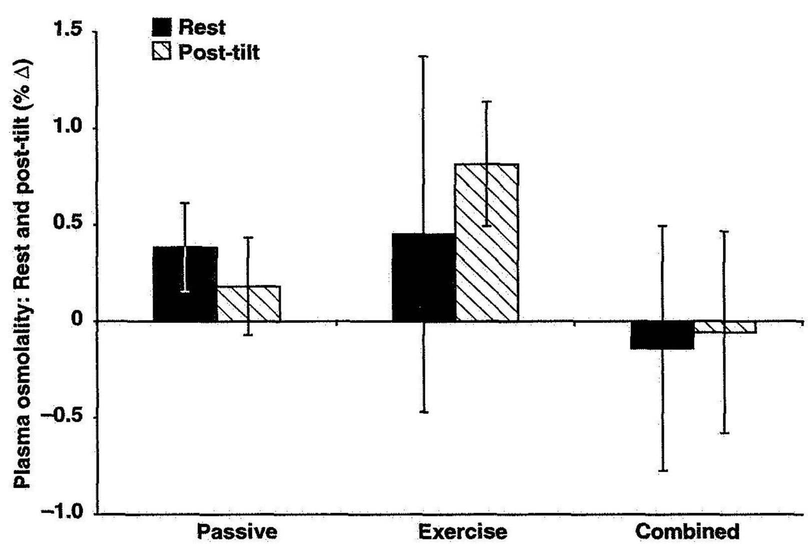


c) Pre- versus post-training, percent change.

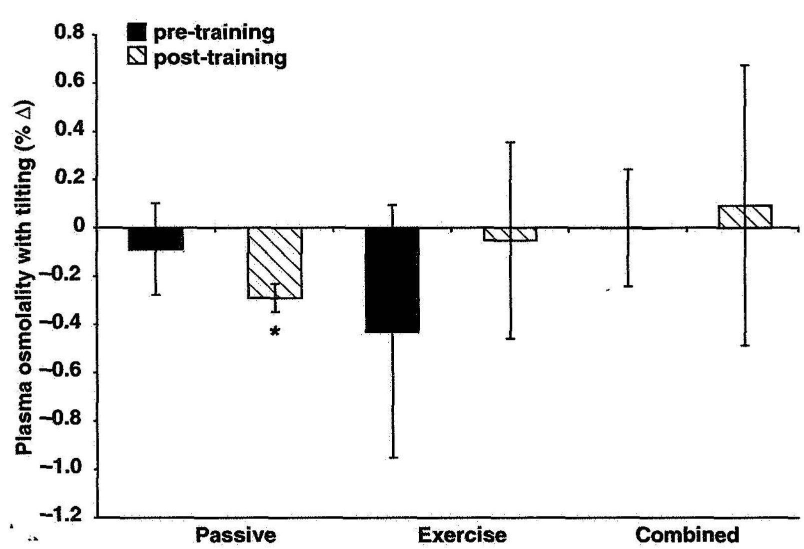
Fig. 35. Mean (±SE) plasma osmotic concentration at rest and post-tilt for the three Phases. Normal range is 285 – 295 mOsmol • kg H_2O^{-1}.



a) Pre- versus post-training, mOsmol • kg^{-1}.

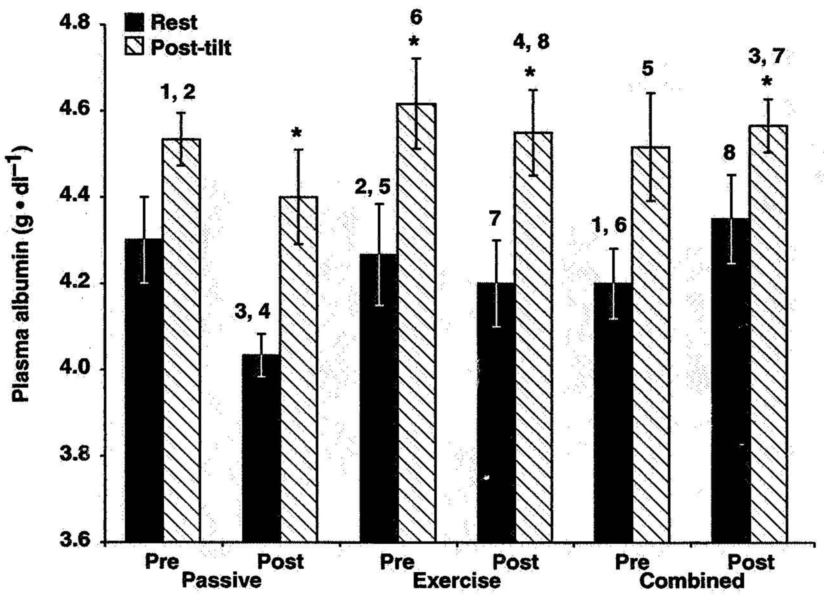


b) After training, percent change.

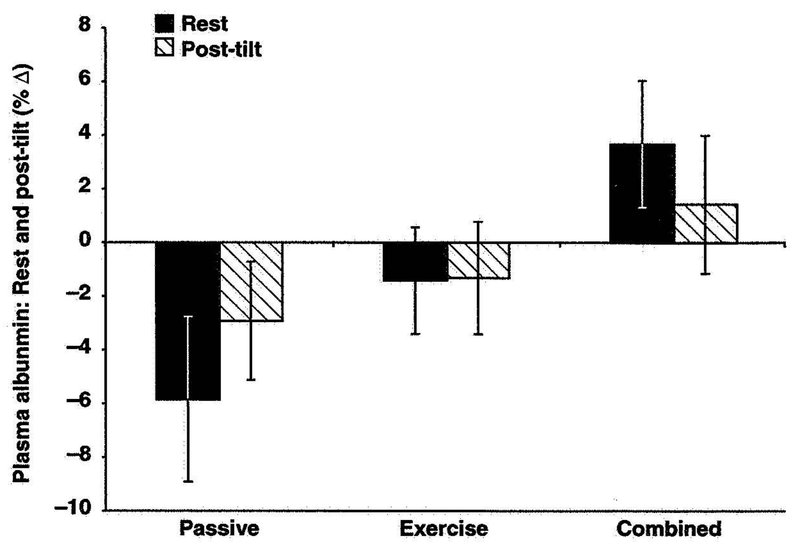


*c) Pre- versus post-training, percent change. * $P < 0.05$ from zero.*

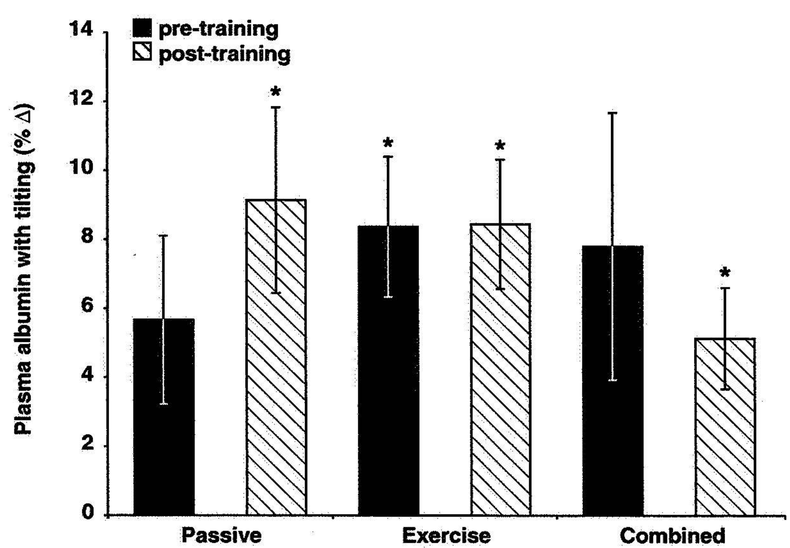
Fig. 36. Mean (±SE) plasma albumin concentration at rest and post-tilt for the three Phases. Normal range is 4.6 – 6.7 g • dl^{-1}.



*a) Pre- versus post-training, g • dl^{-1}. * $P < 0.05$ from corresponding rest value. 1 – 8 are $P < 0.05$ pairs of different values.*

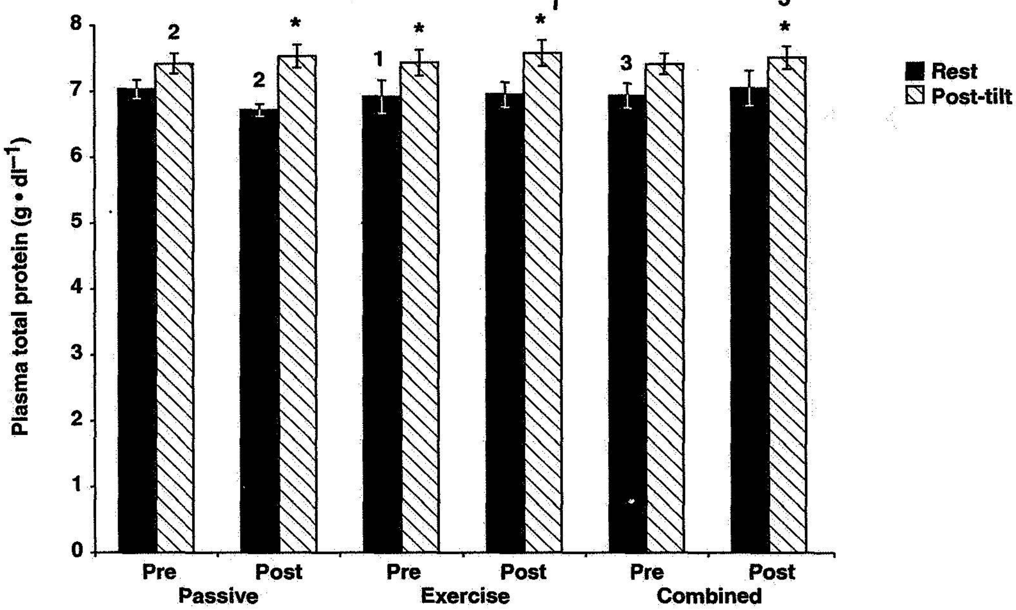


b) After training, percent change.

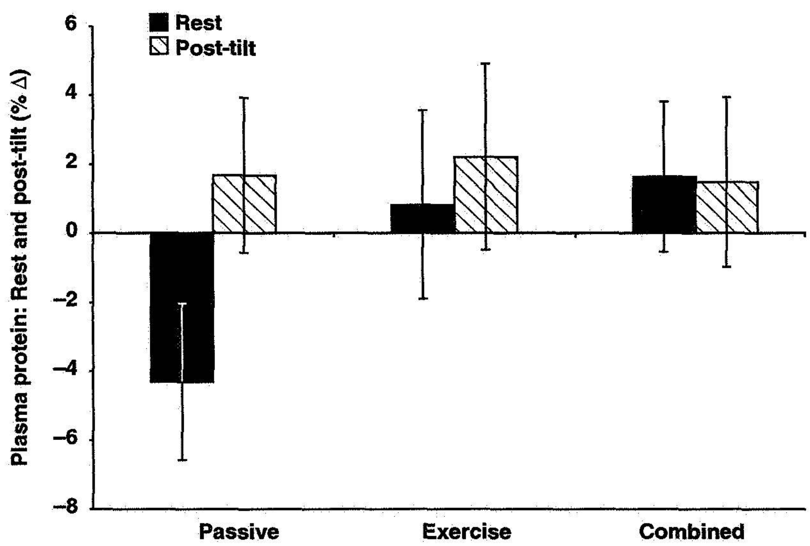


*c) Pre- versus post-training, percent change. * $P < 0.05$ from zero.*

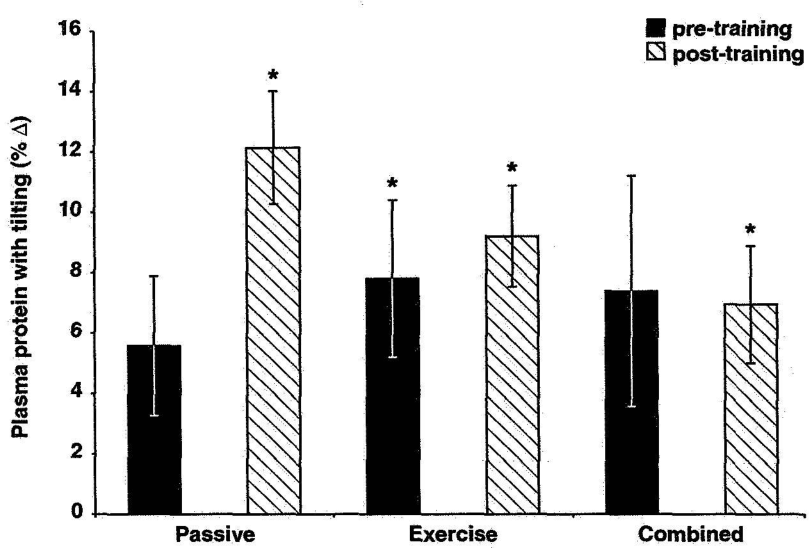
Fig. 37. Mean (±SE) plasma total protein concentration at rest and post-tilt for the three Phases. Normal range is 6 – 8 g • dl⁻¹.



*a) Pre- versus post-training, g • dl⁻¹. * $P < 0.05$ from corresponding rest value. 1, 2, 3 are $P < 0.05$ pairs of different values.*

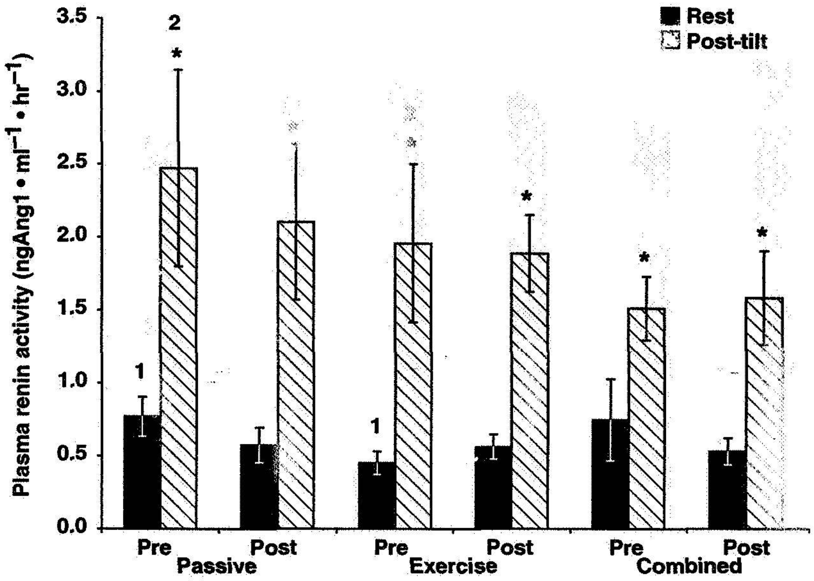


b) After training, percent change.

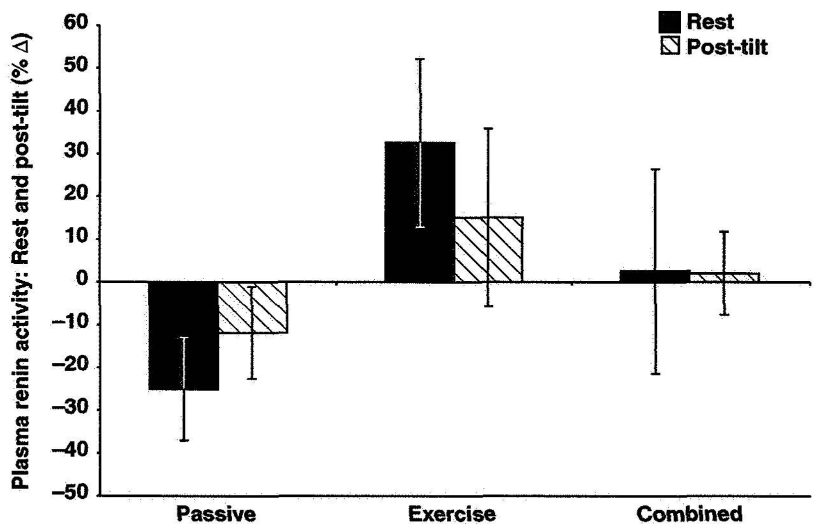


*c) Pre- versus post-training, percent change. * $P < 0.05$ from zero.*

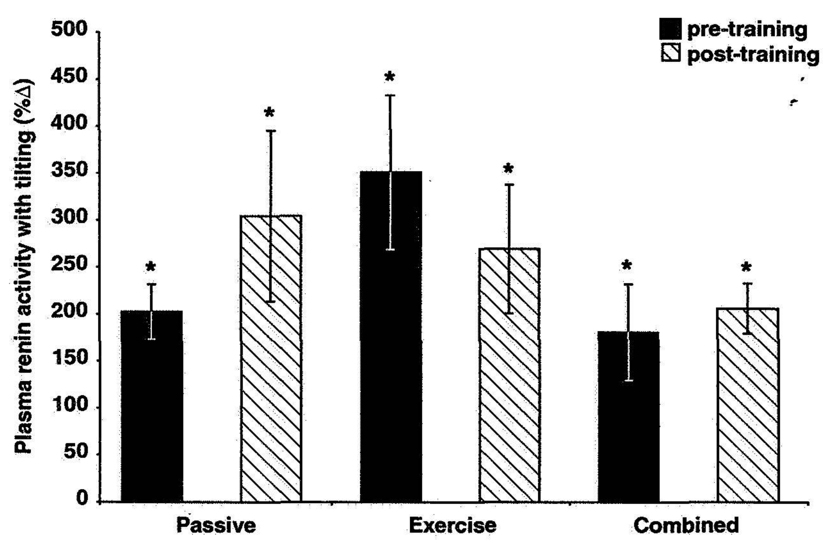
Fig. 38. Mean (±SE) plasma renin acti[illegible]ty at rest and post-tilt for the three Phases. Normal range (supine) is 3.2 ± [illegible]Ang1 • ml^{-1} • hr^{-1}.



*a) Pre- versus post-training, ngAng1 • ml^{-1} • hr^{-1}. * $P < 0.05$ from corresponding rest value. 1, 2 are $P < 0.05$ pairs of different values.*

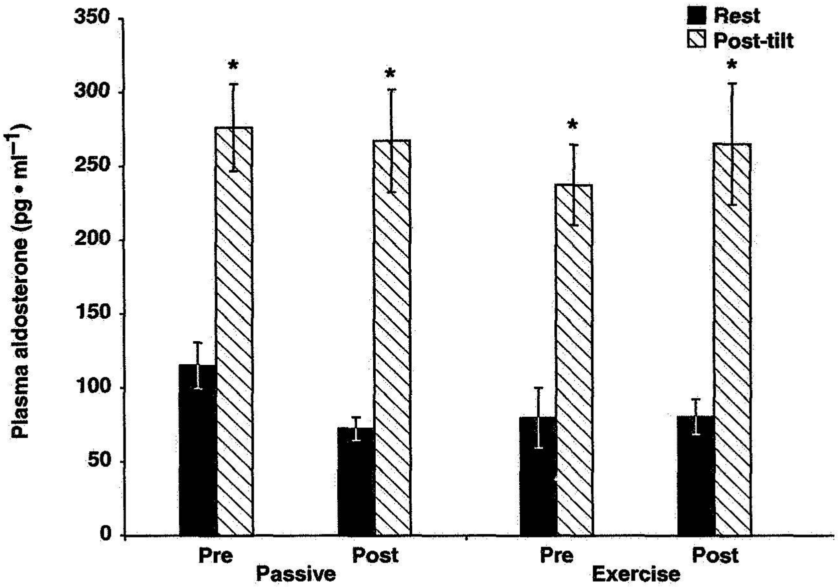


b) After training, percent change.

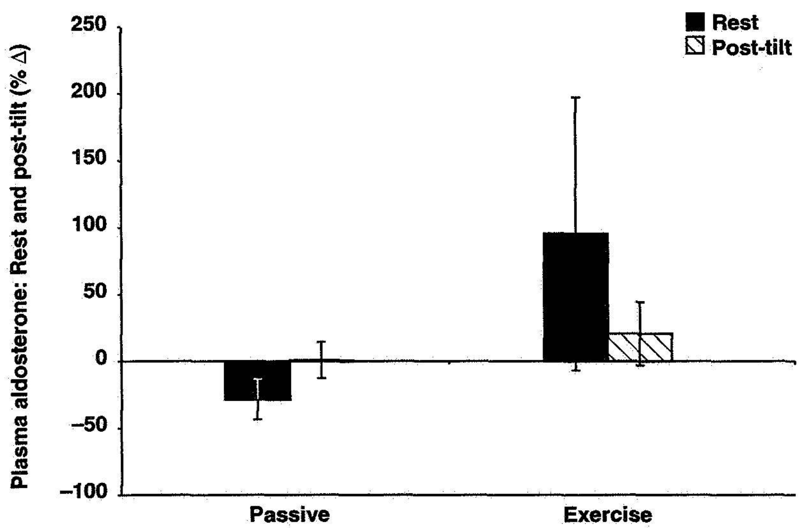


*c) Pre- versus post-training, percent change. * $P < 0.05$ from zero.*

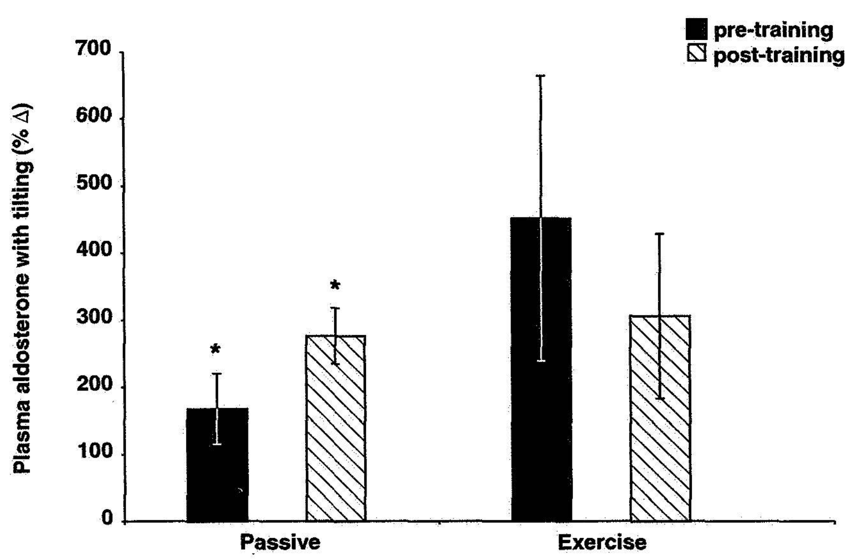
Fig. 39. Mean (±SE) plasma aldosterone concentration at rest and post-tilt for the Passive and Exercise Phases. Normal range (upright) is 50 – 200 pg • ml^{-1}.



*a) Pre- versus post-training, pg • ml^{-1}. * $P < 0.05$ from corresponding rest value.*

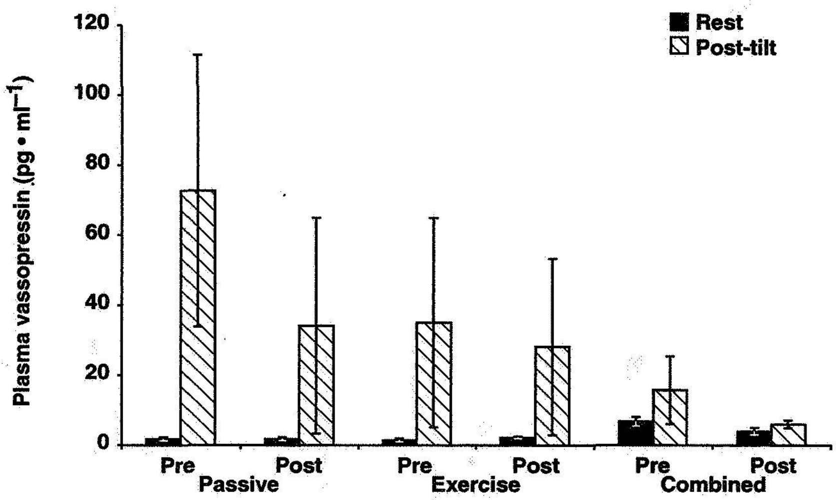


b) After training, percent change.

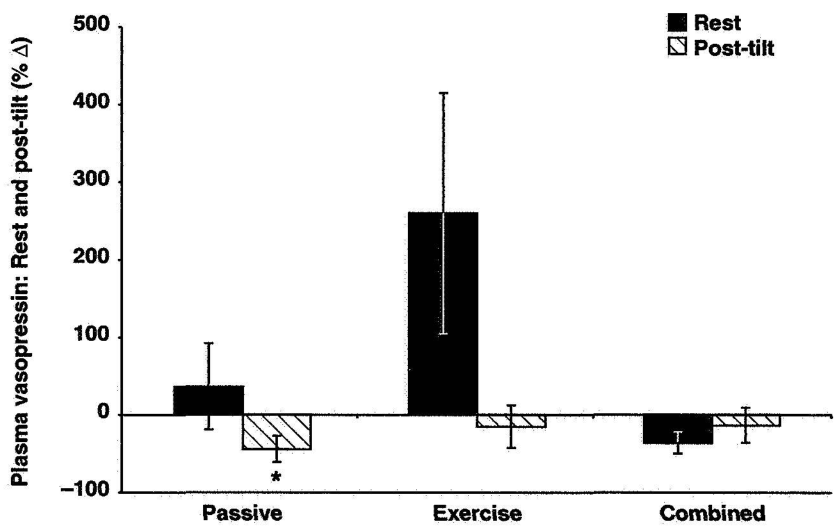


*c) Pre- versus post-training, percent change. * $P < 0.05$ from zero.*

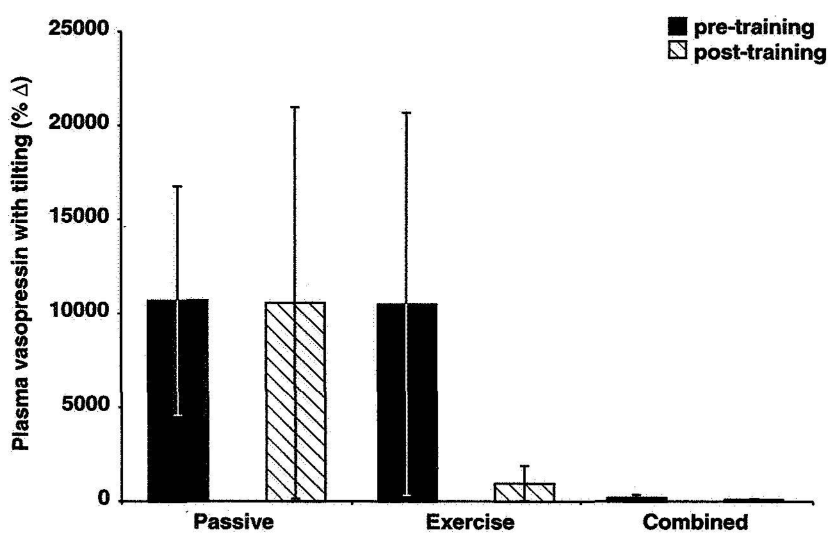
Fig. 40. Mean (±SE) plasma vasopressin concentration at rest and post-tilt for the three Phases. Normal range is 1 – 3 pg • ml^{-1}.



a) Pre- versus post-training, pg • ml^{-1}.

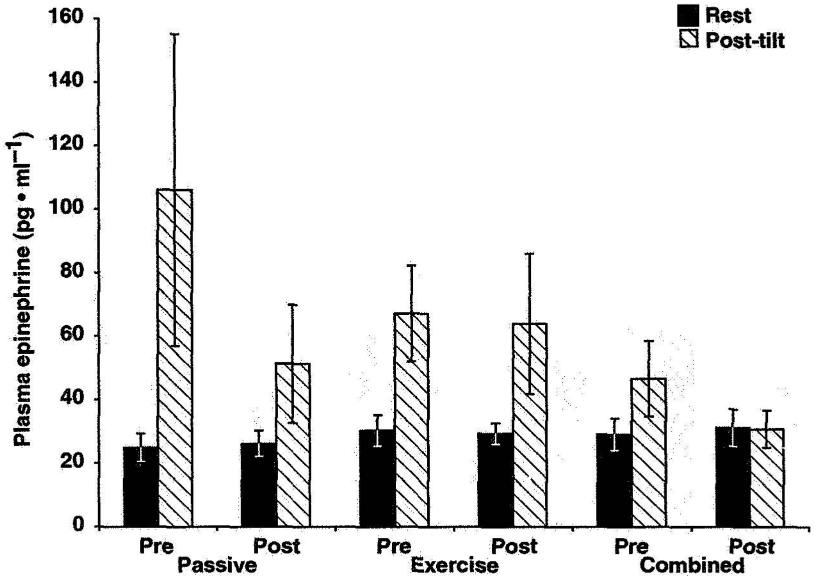


*b) After training, percent change. * $P < 0.05$ from zero.*

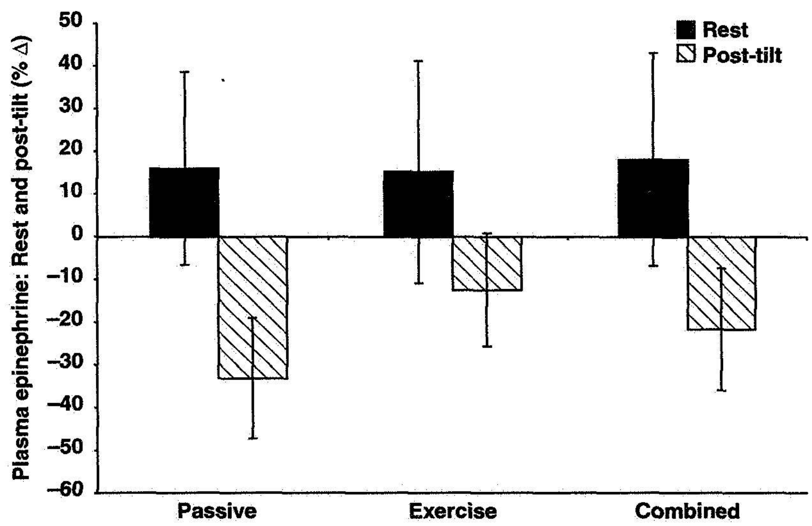


c) Pre- versus post-training, percent change.

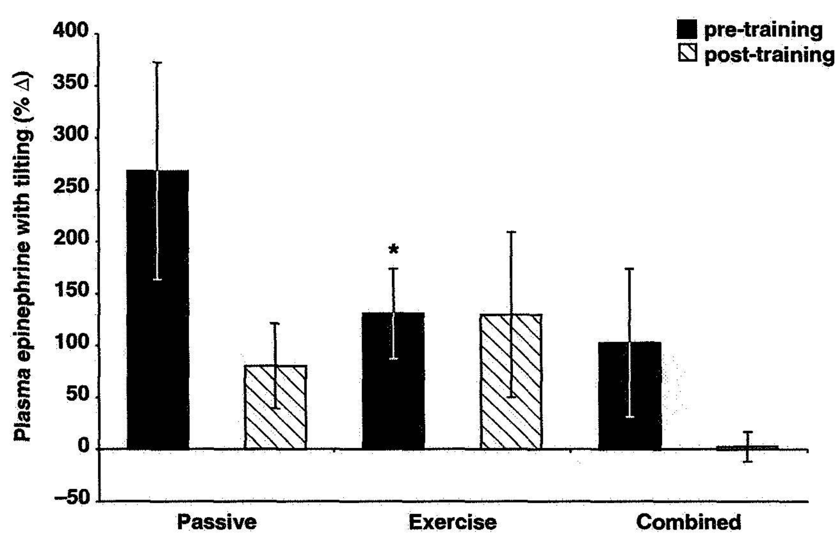
Fig 41. Mean (±SE) plasma epinephrine concentration at rest and post-tilt for the three Phases.



a) Pre- versus post-training, pg • ml^{-1}.

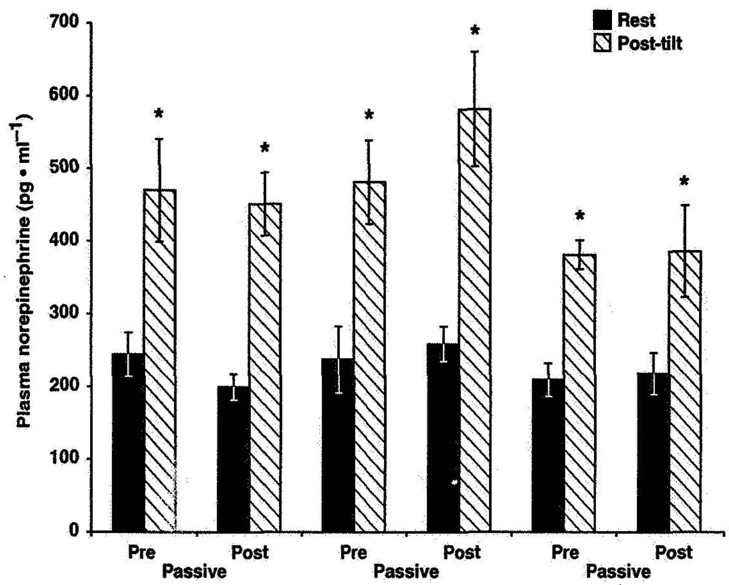


b) After training, percent change.

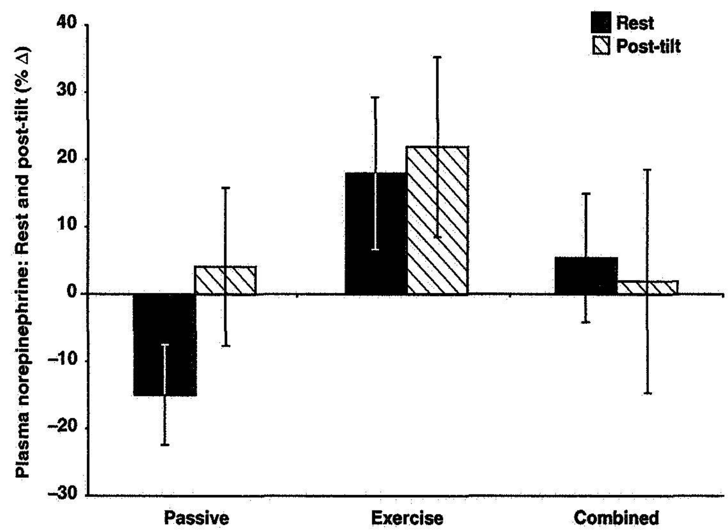


*c) Pre- versus post-training, percent change. * P < 0.05 from zero.*

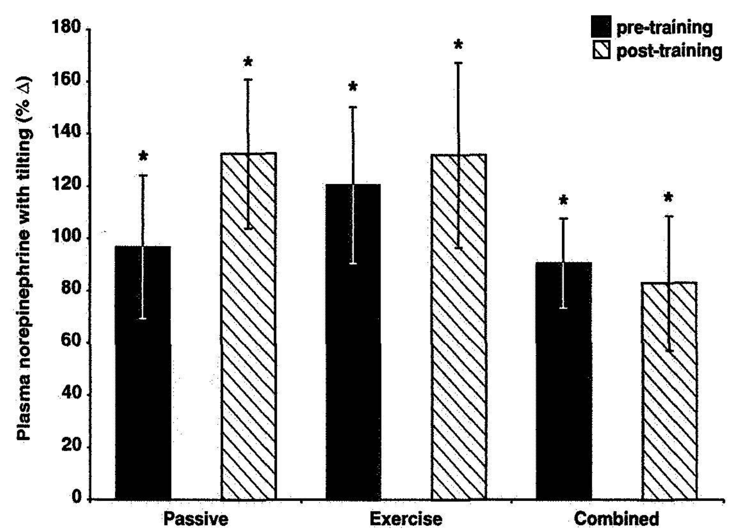
Fig 42. Mean (±SE) plasma norepinephrine concentration at rest and post-tilt for the three Phases.



*a) Pre- versus post-training, pg • ml^{-1}. * $P < 0.05$ from corresponding rest value.*

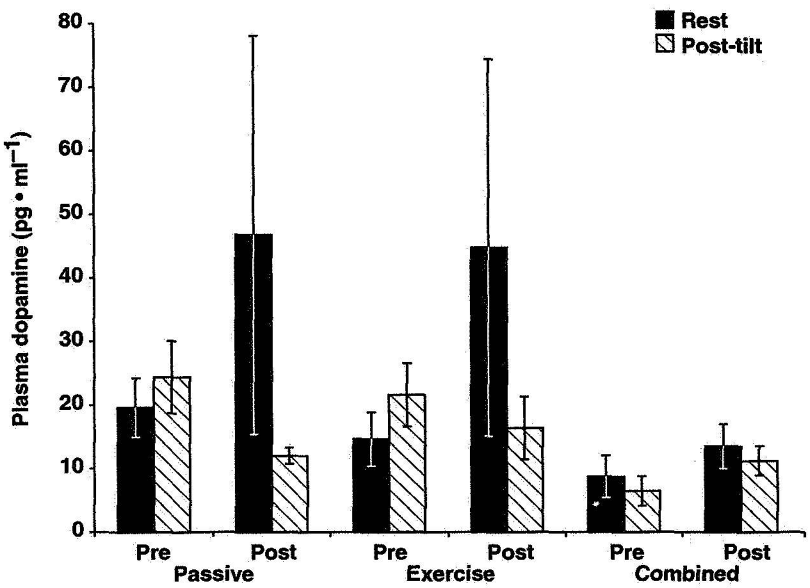


b) After training, percent change.

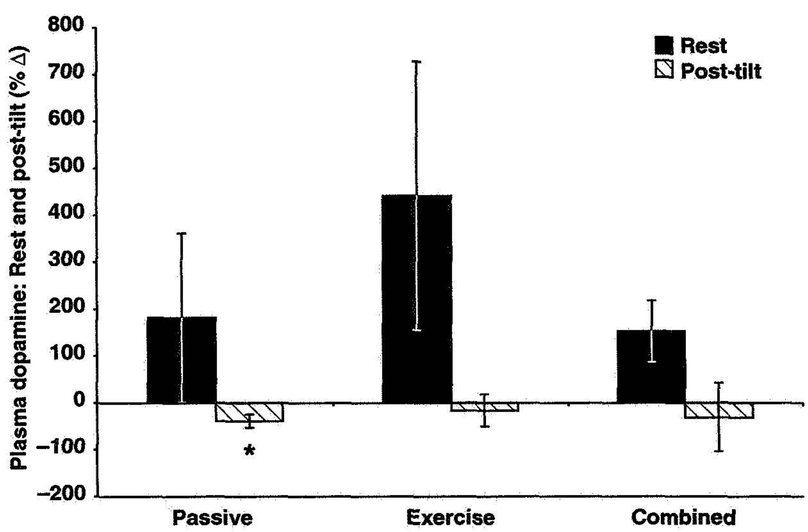


*c) Pre- versus post-training, percent change. * $P < 0.05$ from zero.*

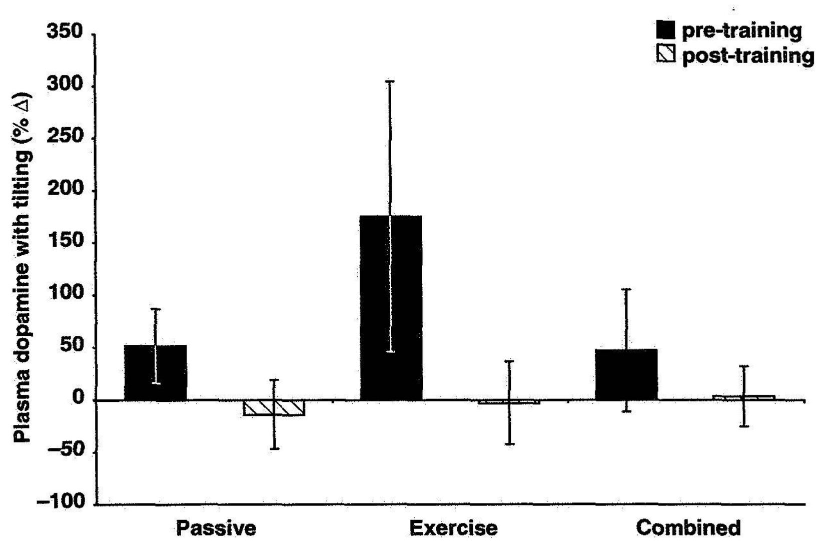
Fig 43. Mean (±SE) plasma dopamine concentration at rest and post-tilt for the three Phases.



a. Pre- versus post-training, pg • ml^{-1}.

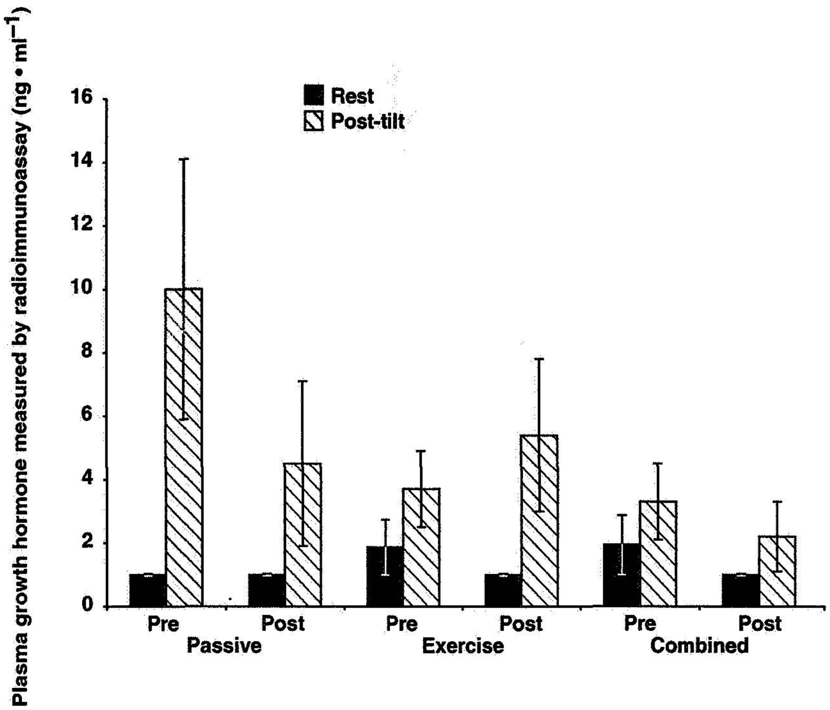


*b) After training, percent change. * P < 0.05 from zero.*

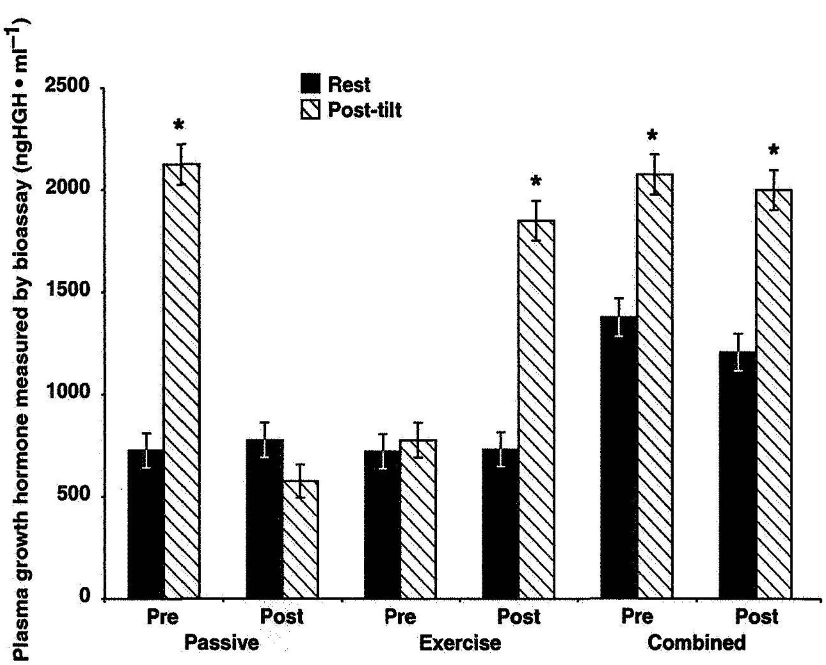


c) Pre- versus post-training, percent change.

Fig. 44. Mean (±SE) plasma growth hormone concentration at rest and post-tilt for the three Phases.



a) Pre- versus post-training by radioimmunoassay, ng • ml^{-1}.



b) Pre- versus post-training by biological assay, ngHGH • ml^{-1}. • P < 0.001 from rest.

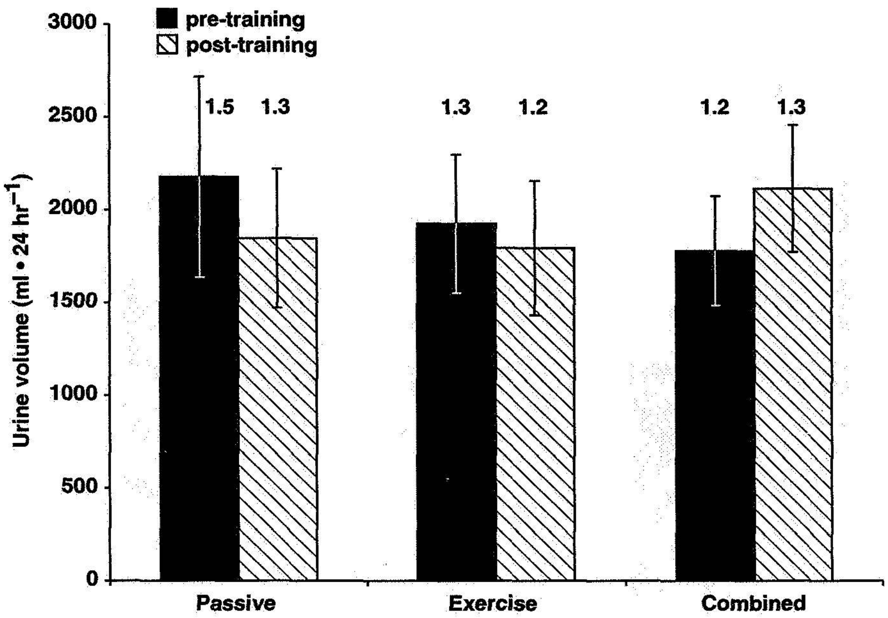


Fig 45. Mean (±SE) urinary volume pre- and post-training for the three Phases, ml • 24 hr^{-1}. Top data are ml • min^{-1}.

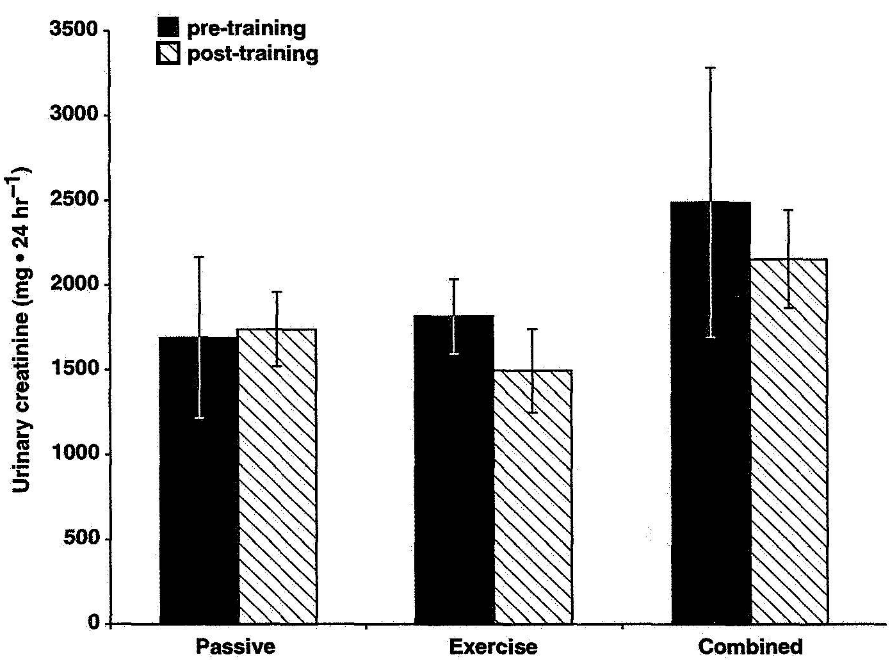


Fig 46. Mean (±SE) urinary creatinine excretion pre- and post-training for the three Phases, mg • 24 hr^{-1}.

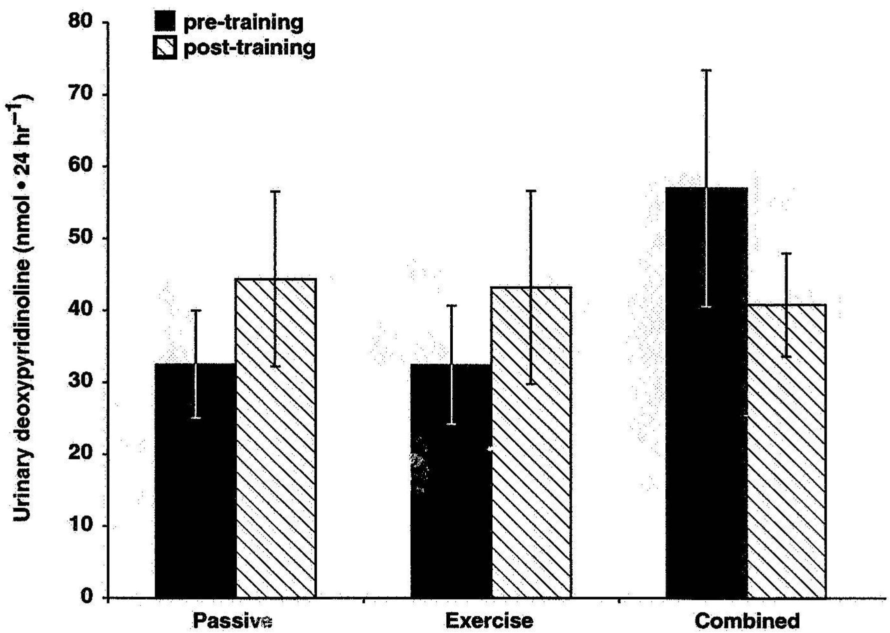


Fig 47. Mean (±SE) urinary deoxypyridinoline excretion pre- and post-training for the three Phases, nmol • 24 hr^{-1}.

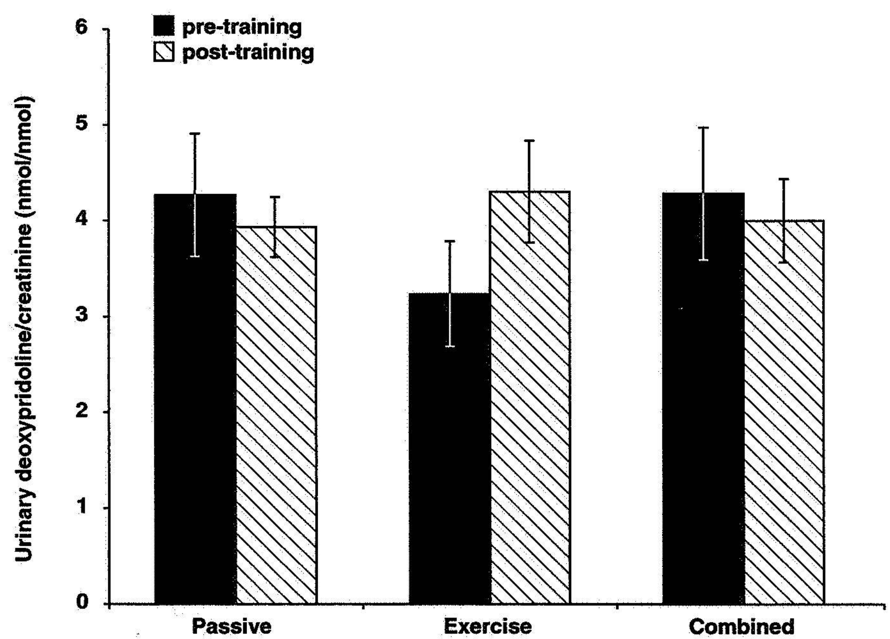


Fig 48. Mean (±SE) urinary deoxypyridinoline/creatinine ratio pre- and post-training for the three Phases nmol/nmol.

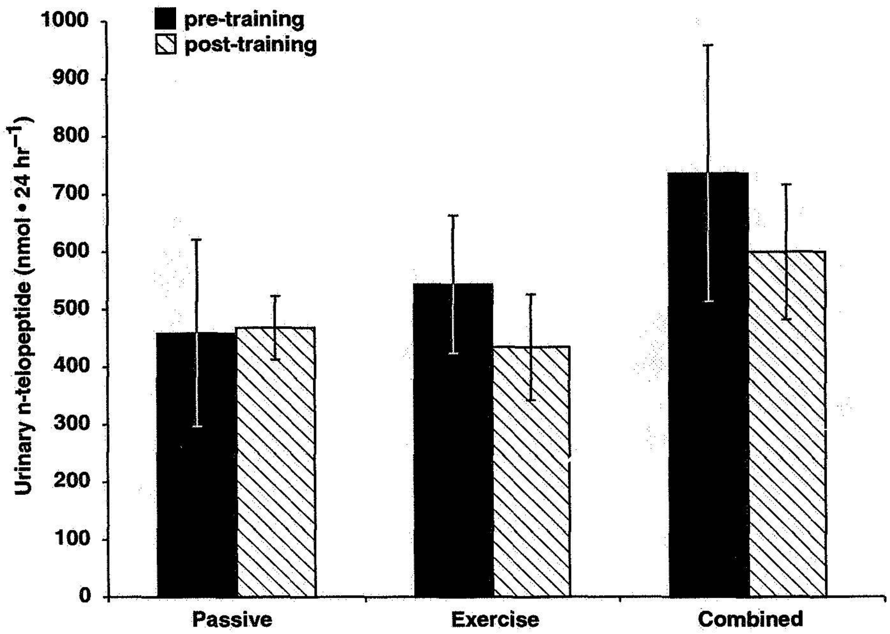


Fig 49. Mean (±SE) urinary n-telopeptide pre- and post-training for the three Phases, nmol • 24 hr^{-1}.

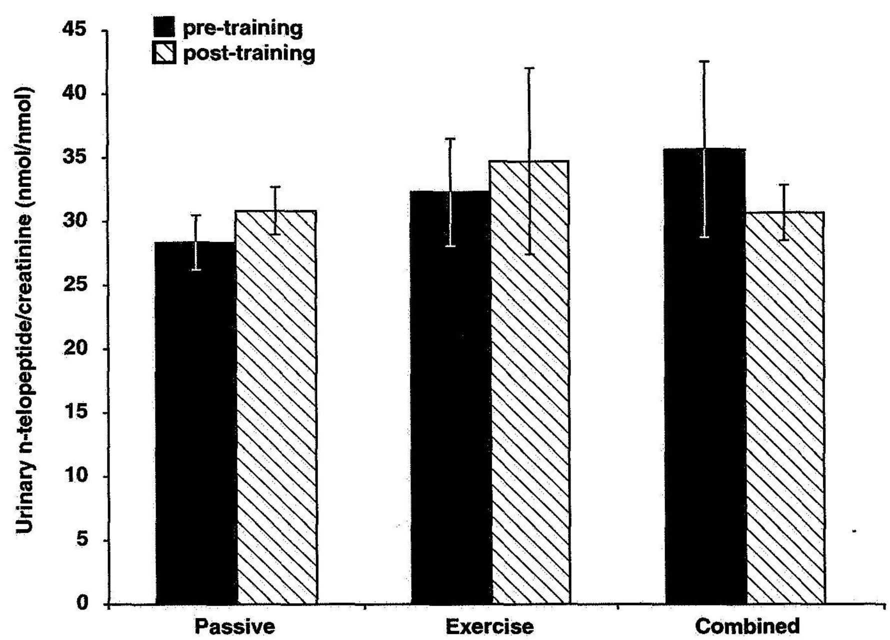


Fig 50. Mean (±SE) urinary n-telopeptide/creatinine ratio pre- and post-training for the three Phases, nmol/nmol.

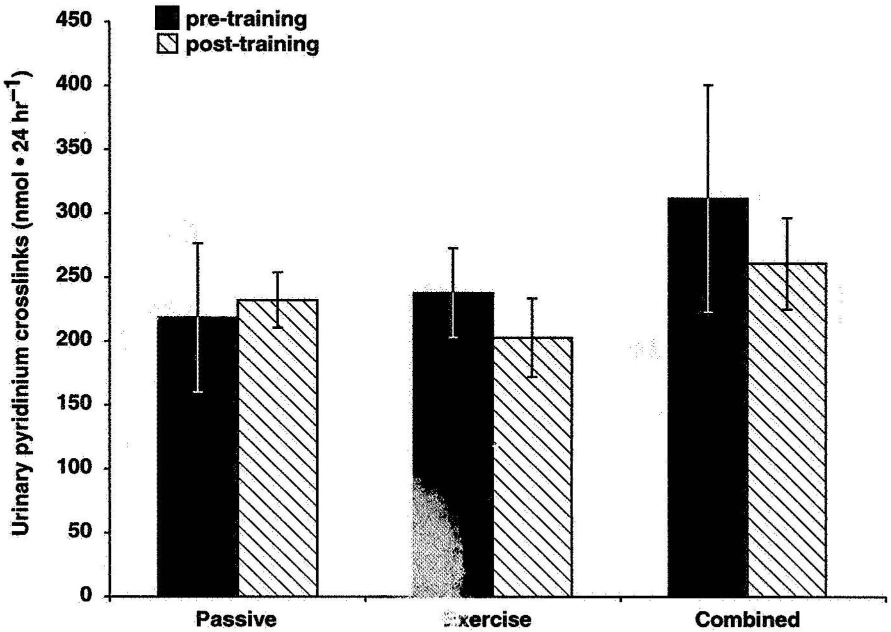


Fig 51. Mean (±SE) urinary pyridinium crosslinks pre- and post-training for the three Phases, nmol • 24 hr^{-1}.

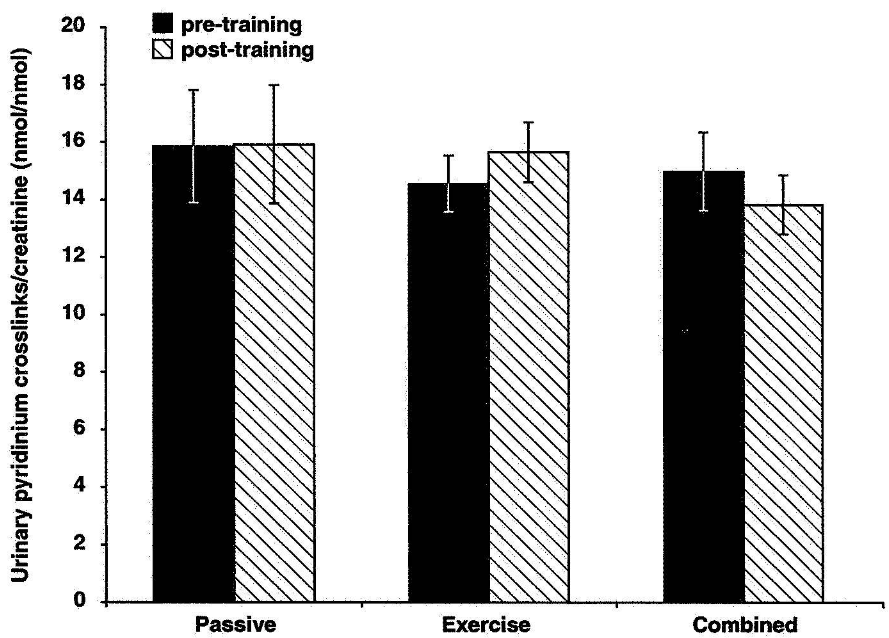


Fig 52. Mean (±SE) urinary pyridinium crosslinks/creatinine ratio pre- and post-training for the three Phases, nmol/nmol.

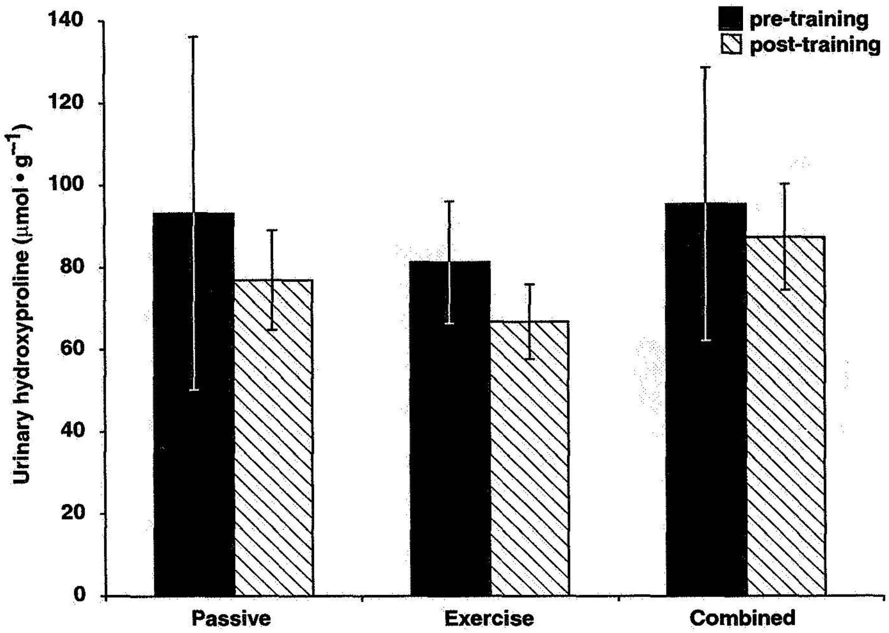


Fig 53. Mean (±SE) urinary hydroxyproline pre- and post-training for the three Phases, µmol • g^{-1}.

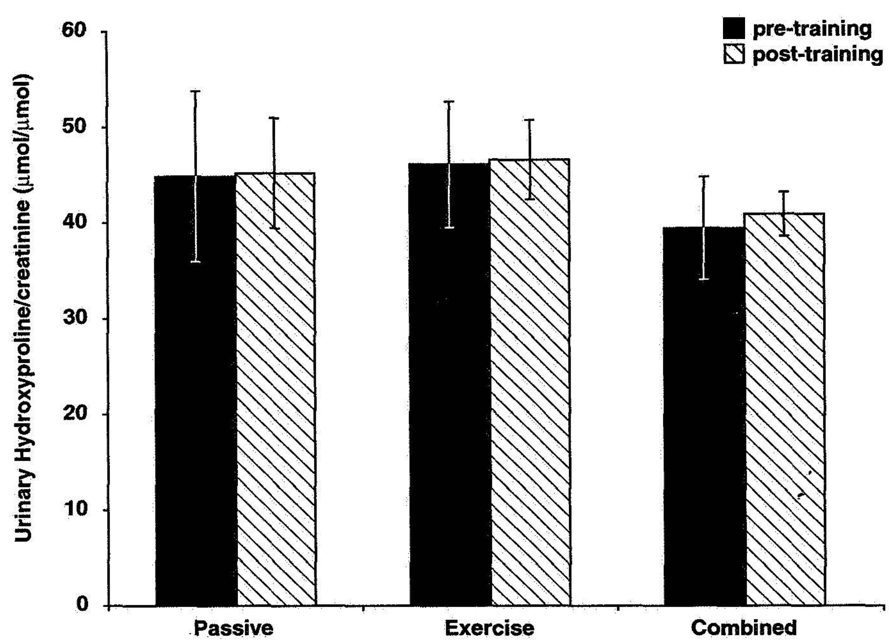


Fig. 54. Mean (±SE) urinary hydroxyproline/creatinine ratio pre- and post-training for the three Phases, µmol/µmol.

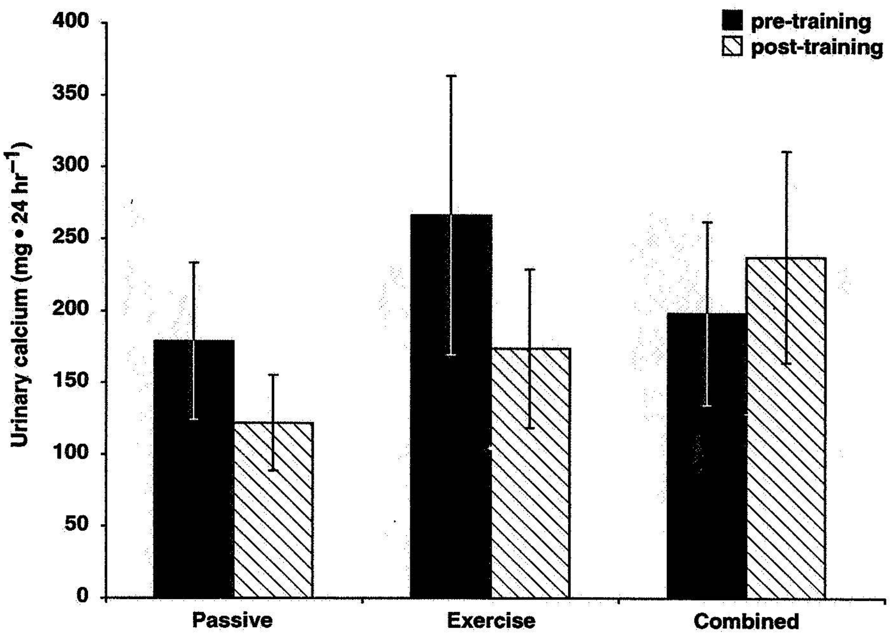


Fig 55. Mean (±SE) urinary calcium excretion pre- and post-training for the three Phases, mg • 24 hr^{-1}.

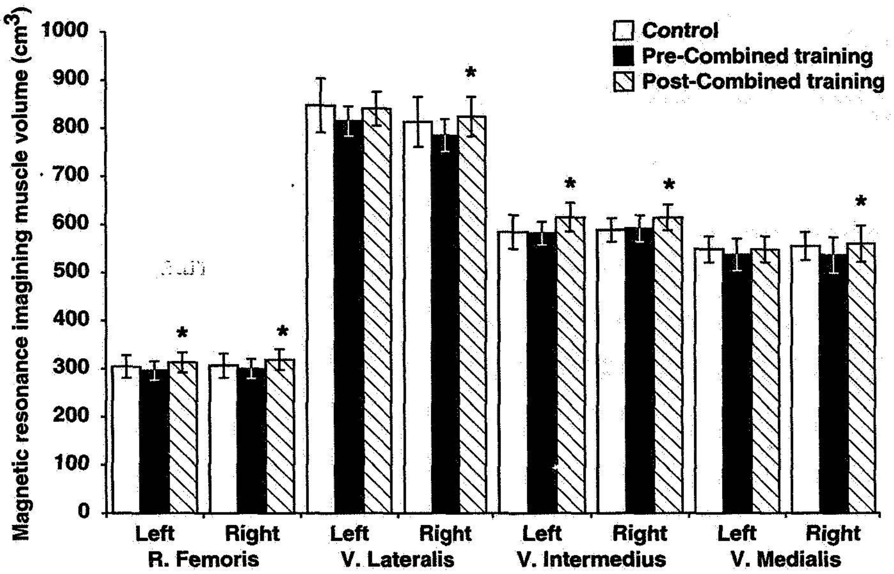


*Fig 56. Mean (±SE) left and right individual quadricep muscle volumes (T1) for control (pre-training) and pre- and post-Combined training for the Combined Phase, cm^3. * $P < 0.05$ from pre-Combined training.*

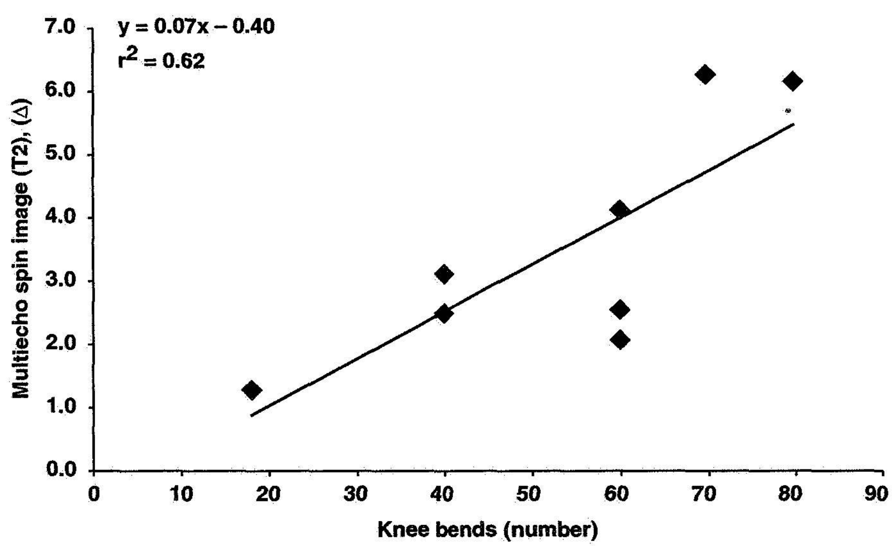


Fig 57. Regression of change in multiecho spin image (T2) on knee work capacity during pre-Combined testing, number of knee bends.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
Month 1998

3. REPORT TYPE AND DATES COVERED
Technical Memorandum

4. TITLE AND SUBTITLE
Effect of Exercise Training and +Gz Acceleration Training on Men

5. FUNDING NUMBERS
UPN 111-10-20

6. AUTHOR(S)
John E. Greenleaf, Shawn R. Siminson, Jodie M. Stocks, Joyce Evans, Charles F. Knapp, Stephenie A. Cowell, Kendra N. Bailey-Pemberton, Heather W. Wilson, Jamie M. Vener, Simon N. Evetts, Peter A. Hardy, Richard E. Grindland, Helmut Hinghofer-Szalkay, Scott M. Smith, Michael G. Ziegler, David R. Brown, David G. Evans, Fritz B. Moore, and David T. Quach

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Ames Research Center
Moffett Field, CA 94035-1000

8. PERFORMING ORGANIZATION REPORT NUMBER
A-00V0046

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA/TM–2001-210926

11. SUPPLEMENTARY NOTES
Point of Contact: John Greenleaf, Ames Research Center, MS 221A-2, Moffett Field, CA 94035-1000
(650) 604-6604

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified — Unlimited
Subject Category 52 Distribution: Standard
Availability: NASA CASI (301) 621-0390

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
Countermeasures for reduction in work capacity (maximal oxygen uptake and strength) during spaceflight and enhanced orthostatic intolerance during re-entry, landing and egress from the return vehicle are continuing problems. The purpose for this study was to test the hypothesis that passive-acceleration training; supine, interval, exercise plus acceleration training; and exercise combined with acceleration training would improve orthostatic tolerance in ambulatory men; and that addition of the aerobic exercise conditioning would not alter this improved tolerance from that of passive-acceleration training. Seven men (24-38 yr) underwent "Passive" training on the Ames human-powered centrifuge (HPC) for 30 min; "Exercise" training on the cycle ergometer with constant +Gz acceleration; and "Combined" exercise training at 40% to 90% of the HPC $+Gz_{max}$ exercise level. Maximal supine exercise loads increased significant ($P<0.05$) by 8.3% (Passive), 12.6% (Exercise), and by 15.4% (Combined) after training, but their post-training maximal oxygen uptakes and maximal heart rates were unchanged. Maximal time to fatigue (endurance) was unchanged with Passive but was increased ($P<0.05$) with Exercise and Combined training. Thus, the exercise in the Exercise and Combined training Phases resulted in greater maximal loads and endurance without effect on maximal oxygen uptake or heart rate. There was a 4% to 6% increase ($P<0.05$) in all four quadriceps muscle volumes (right and left) after post-Combined training. Resting pre-tilt heart rate was elevated by 12.9% ($P<0.05$) only after Passive training suggesting that the exercise training attenuated the HR response. Plasma volume (% Δ) was uniformly decreased by 8% to 14% ($P<0.05$) at tilt-tolerance pre- vs. post-training indicating essentially no effect of training on the level of hypovolemia. Post-training tilt-tolerance time and heart rate were increased ($P<0.05$) only with Passive training by 37.8% and by 29.1%, respectively. Thus, addition of exercise training appeared to attenuate the increased Passive tilt-tolerance.

14. SUBJECT TERMS
Acceleration, Exercise, Training, Deconditioning

15. NUMBER OF PAGES
138

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified		